Strategic Plan for the Restoration of Diadromous Fishes to the Penobscot River

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List of Acronyms

ACFHP	Atlantic Coastal Fish Habitat Partnership
ASC	Atlantic Salmon Commission
ASF	Atlantic Salmon Federation
ASMFC	Atlantic States Marine Fisheries Commission
CPUE	Catch-per-unit effort
CSE	Conservation Spawning Escapement
EBTJV	Eastern Brook Trout Joint Venture
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
HUC	Hydrologic Unit Code
ICES	International Council for the Exploration of the Sea
LURC	Land Use Regulatory Commission (Maine)
MDEP	Maine Department of Environmental Protection
MDIFW	Maine Department of Inland Fisheries and Wildlife
MDMR	Maine Department of Marine Resources
MDOC	Maine Department of Conservation
MFS	Maine Forest Service
NASCO	North Atlantic Salmon Conservation Organization
NEAC	New England Atlantic Salmon Coalition
NEJV	New England Joint Venture
NPDES	National Pollution Discharge Elimination System
NRPA	Natural Resource Protection Act
NGO	Non-governmental organizations (e.g., Atlantic Salmon Federation, Watershed Councils, Trout Unlimited, Local Land Trusts,)
NOAA	National Oceanographic and Atmospheric Administration
NRCS	Natural Resource Conservation Service
PIN	Penobscot Indian Nation
PNWRP	Penobscot Nation Water Resources Program
PPL	PPL Corporation
PRRT	Penobscot River Restoration Trust
PRRP	Penobscot River Restoration Project
PRASWG	Penobscot River American Shad Working Group
TU	Trout Unlimited
UM	University of Maine
U.S. EPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Executive Summary

This is a strategic plan for the *Restoration of Diadromous Fishes to the Penobscot River*. The overarching goal for the river is to restore and guide the management of diadromous fish populations, aquatic resources and the ecosystems on which they depend, for their intrinsic, ecological, economic, recreational, scientific, and educational values for use by the public. The Department of Marine Resources and Department of Inland Fisheries and Wildlife are the State agencies responsible for developing and carrying out the plan and the Maine Atlantic Salmon Commission has policy authority for Atlantic salmon. In addition, the Departments are working with the Penobscot Indian Nation, and the US Fish and Wildlife Service, and National Oceanic and Atmospheric Administration National Marine Fisheries Service, who have federal trust responsibly for species included in the plan. The Departments are also working with the Penobscot River Restoration Trust, PPL, researchers, other state and federal agencies and other stakeholders with an interest in the basin. The plan recognizes that restoring ecosystem processes and integrated multi-species fish management will increase potential success, and that working cooperatively with other State and Federal agencies, researchers and stakeholders are essential to the success of this effort.

This plan includes four strategic goals: (1) coordinating management activities, (2) providing safe and effective upstream and downstream passage for diadromous fishes, (3) maintaining or improving abiotic (physical) and biotic habitat for diadromous fishes using ecosystem-based management, and (4) rebuilding diadromous fish populations. An interagency technical committee will develop an operational plan that details how these goals will be achieved, however, restoration actions for species such as American shad and alewife will begin prior to the completion of the operational plan and Atlantic salmon efforts will increase. An advisory committee will be appointed to work with the interagency technical committee.

Introduction

The Penobscot River is New England's second largest river, with a watershed that covers about a third of the State of Maine (approximately 22,300 km^2; 8,600 mi^2). It is 563 km long (350 miles) and has a total fall of 488 m (1,770 feet) from its highest point, Penobscot Lake. There are diverse aquatic environments in the watershed with over 2,575 km (1,600 miles) of streams and rivers and more than 625 lakes and ponds with a total surface area of 103,036 ha (254,600 acres).

For thousands of years, diadromous fishes migrated through much of the basin, providing a connection between the Gulf of Maine and inland terrestrial and aquatic ecosystems (Figure 1). For thousands of years, members of the Penobscot Indian Nation living along the river and its tributaries sought the migratory fish of the Penobscot River, as did the European explorers and settlers. Commercial harvest of the Penobscot River's migratory fish species began soon after the settlement of Bangor and Bucksport in the1760s. From the late 1700s to 1830s, fishing was conducted primarily with seines, drift nets and brush weirs in the tidal portion of the river from Bangor to Bucksport. Fishtraps, nets and spears were used at the river's various rapids from Old Town to Bangor. As the 19th century progressed, weirs became the dominant fishing method, with most located in the river's estuary and Penobscot Bay. Species targeted included Atlantic salmon, striped bass, American shad, alewives, smelt and tomcod. It is uncertain if sturgeon were commercially targeted, although one report states that large sturgeon were often caught in drift nets and seines set for other species (Appendix A).

The Penobscot commercial fishery was radically altered in 1834 with the construction of a large dam at Eddington Bend near the site of the contemporary Veazie dam. Dams at Great Works and Old Town, built several years prior, only partially spanned the river. The Veazie dam was the first to completely block the river. Despite state fish passage laws and the dam company's Legislature charter, which required the provision of fish passage, no fishway was built at the dam. Dam construction on the lower Penobscot in the 1830s greatly impacted the rivers' striped bass and sturgeon. The Veazie Dam prevented these fish from reaching their entire spawning habitat above the river's head of tide. American shad were greatly impacted due to their inability to leap over lower river dams. The increasing number of mill dams and logging dams on lake and pond outlets prevented alewives from reaching most of their native habitat in the Penobscot River. Due to their leaping ability, some Atlantic salmon were able to leap over the lower dams and reach the river's upper tributaries.

In response to the sharp decline of migratory fish populations across the state, the Maine Legislature created the Maine Fisheries Commission in 1868 and charged it with rebuilding the state's migratory fish stocks. The first commissioners, Charles Atkins and Nathan Foster, conducted extensive surveys of each river, interviewed hundreds of commercial fisherman, and inspected most major dams. They identified the primary obstacles to restoration as impassable dams, over-fishing and pollution of the waters.

The health of the Penobscot River's migratory fish species has long been closely tied to the region's timber economy. The enormous quantities of virgin timber in the Penobscot

River headwaters in the 1830s provided the investment capital to pay for large main-stem dams constructed during this period. These dams provided the mechanical power to cut and process billions of board feet of saw logs during the 19th century. By the 1840s all of the forests within 50 miles of Bangor were cut over. By the 1880s even the most remote parts of the Penobscot watershed had been heavily cut.

In 1900, the Penobscot River's timber economy shifted to pulp and paper production, which could utilize trees of much smaller diameter than the saw log industry. Construction of pulp and paper mills along the river began in the early 1900s in Millinocket, Old Town, Brewer, and Lincoln. Numerous textile and shoe factories along the river were also built during this period. Because these industries required chemical processes, pollution of the Penobscot River with industrial waste increased dramatically.

Since 1959, multiple reports have documented the issues facing diadromous fish restoration in the Penobscot drainage. Most of the problems in the drainage relate to upstream and downstream passage, water quality, quality of habitat, changes in fish community assemblages and lack of access to historical habitat (Baum 1983; Baum 1995; Baum 1997a; Beland 1984; Bernier et al. 1995; Cutting 1963; Everhart and Cutting 1967; Fay et al. 2006; Lower Penobscot River Basin Comprehensive Settlement Accord 2004; PRASWG 2001; Trefts 2006). Many of these threats are due to land use practices and development, and the subsequent alteration of ecosystem functions. Declining populations are a symptom of an underlying systemic problem, which have multiple causes, generally due to human impacts (Czech and Krausman 2001; National Research Council 1995; Rohlf 1989). Therefore, this plan builds on previous reports by outlining actions to integrate fisheries management and restoring degraded ecosystem functions and processes. The aim is to eliminate or mitigate the causes (Beechie and Bolton 1999) of degraded ecological processes (Bastian 2001; Bell et al. 1997; Turner et al. 2001; Ward et al. 2002), because this can assist in the restoration efforts (Beechie and Bolton 1999).

The overarching goal of the plan is to restore and guide management of diadromous fish populations, aquatic resources and the ecosystems on which they depend, for their intrinsic, ecological, economic, recreational, scientific, and educational values for use by the public. The State fisheries agencies, the Department of Marine Resources (MDMR) and the Department of Inland Fisheries and Wildlife (MDIFW) (Appendix B) are committed to working together and in cooperation with the Penobscot Indian Nation (PIN), the US Fish and Wildlife Service (USFWS), and National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries), in this effort. There are also many stakeholders with an interest in the watershed that have led and continue to lead restoration efforts. Various non-governmental organizations (NGOs) have worked to restore alewives by succeeding with three barriers removals in Souadabscook Stream, the removal of the Brownville Dam and active efforts to improve fish passage in Blackman Stream and Sedgeunkedunk Stream. Researchers from the University of Maine (UM) and other institutions have worked cooperatively with state and federal agencies, providing needed information on multiple fish species and the environment throughout the basin. The Penobscot River Restoration Trust (PRRT or Trust) has worked tirelessly on the Penobscot River Restoration Project (PRRP).

This Strategic Plan is intended to complement the PRRP, which was made possible by the Lower Penobscot River Multiparty Settlement Agreement signed in June 2004 by PPL Corporation (PPL), state and federal resource agencies, the PIN, and various NGOs. This unprecedented and historic agreement provides the PRRT, a non-profit organization, the option to purchase three dams from PPL, decommission and remove the two lowermost dams on the main stem of the river (Veazie and Great Works), and decommission and pursue construction of an innovative experimental fish bypass around the Howland dam, located upstream on the Piscataquis River.

In negotiating the agreement with PPL, the state and other conservation interests recognized that previous management strategies involving installation and operation of fish passage facilities at dams on the Penobscot would not accomplish overall diadromous fish restoration goals. Some species that historically occurred in the river, such as Atlantic and shortnose sturgeon, rainbow smelt and striped bass, will not use conventional fish passage facilities. The continuing presence of multiple dams on the lower main stem of the river, even if they include state-of-the-art fishways, also results in cumulative losses of Atlantic salmon, American shad and other migrating fish due to inefficiencies at each facility, making it unlikely that restoration of fish runs to upstream habitats will occur. Therefore, in order to fully restore historic fish runs and ensure migratory access to important habitats in the watershed, the number of dams needs to be strategically reduced.

The three dams that PPL would sell to the PRRT are not likely to be removed or altered until sometime between 2010-2012, based current projections. Until then, the resource agencies will work cooperatively with the PRRT on issues related to the dam removals, and on the design, construction, and evaluation of the Howland fish bypass. The agreement also gives PPL the opportunity to increase power generation at six existing dams, some of which has already begun. This will help maintain more than 95% of the renewable hydropower energy currently generated at dams on the river. PPL is also required to improve fish passage at four additional dams, directly benefiting American eels and other species. In short, the PRRP is intended to lay the foundation for the restoration of self sustaining populations of native sea-run fish through improved access to nearly 1,000 miles of historic habitat, renew opportunities for the PIN to exercise sustenance fishing rights; and create new opportunities for tourism, business and communities (PRRT 2006).

The state also intends to follow through with its fisheries planning for the Penobscot even if the PRRT does not exercise its purchase option and remove the lower dams on the river. In that case, PPL has agreed to make improvements to fish passage at Veazie and Milford, which will greatly enhance opportunities for restoration of most of the species, particularly shad and river herring.

This plan presents a long-term vision and is intended to provide guidance to an interagency technical committee on restoration actions for multiple species over the next 25 years through the identification of shared goals, objectives and strategies for restoration, recovery, and management of multiple fish species and ecosystem processes, using an adaptive management approach. The key ecosystem processes are hydrology, connectivity, species assemblages, food web interactions, energy flow, and mineral cycles. Understanding these processes are going to require collaborative efforts with researchers and other state and federal agencies. A primary responsibility of the interagency committee will be to address inter-agency management issues in areas of overlapping jurisdiction and directing strategic actions through the development of an operational plan by 2010. The operational plan will detail actions to accomplish the strategic plan objectives, will incorporate multi-species management, and will be revised as needed in conjunction with barrier removals and improved access to habitat. There is an urgency to begin restoration efforts for shad and river herring and to increase efforts to restore Atlantic salmon; therefore actions will begin prior to the completion and adoption of the operational plan. The 25-year time frame for the Strategic Plan, spanning 2008 through 2032, has two stages. The first stage will be through the completion of the Penobscot River Restoration Project (approximately 2008-2012) and the second stage will be a 20-year period after the Project is complete (approximately 2012-2032). An Advisory Committee will be appointed to work with the interagency technical committee. The role of the Advisory Council is to provide advice to the agencies with management authority on issues pertaining to the operational plan, including but not limited to, the needs and priorities of the private sector, conservation measures, improvement of communications between NGO and government interests, and programs to enhance the status of diadromous species. In addition, PPL will be invited to attend advisory committee meetings, but will also be consulted annually regarding issues pertaining to their facilities.

Vision

The vision for the Penobscot River basin is to have adequate, high quality habitat accessible to support the restoration and enhancement of functional ecosystem processes, aquatic organism communities, in order to have restored and well managed populations of diadromous fish by 2032.

Description of the Basin

Sub-Watersheds

For the purposes of this plan the Penobscot River basin was divided into major sub-watersheds based on U.S. Geological Survey (USGS) Hydrologic Unit Code (HUC) system level 3 (HUC 8)(Table 1; Figure 2). These sub-watersheds and their areas are the East Branch Penobscot (2,896 km^2; 1,118 mi^2), West Branch Penobscot (5,518 km^2; 2,131 mi^2), Mattawamkeag (3,906 km^2; 1,508 mi^2), Piscataquis (3,778 km^2; 1,459 mi^2), and Lower Penobscot, which includes the mainstem and tributaries from the confluence of the East and West branches to the ocean (6,167 km^2; 2,381 mi^2). The Lower Penobscot includes a number of smaller tributaries that support diadromous fish, including the Passadumkeag River, Kenduskeag Stream, Marsh Stream, and Cove Brook. Additional sub-watersheds identified in the plan will not be based on USGS

HUC levels, but on the management of fish communities in the basin. The Operational Plan will break the HUCs into management reaches for developing restoration and management goals and objectives for each species.

River hydrology

Water discharge data has been recorded for more than 80 years at three USGS gauging stations that are located on the mainstem Penobscot River at West Enfield, the Piscataquis River at Dover-Foxcroft, and the East Branch Penobscot at Grindstone. Seven other stations, which have been operational for shorter periods of time, are located on the Piscataquis River at Blanchard and Medford, Kingsbury Stream at Abbot Village, the Mattawamkeag River at Mattawamkeag, the mainstem Penobscot at Eddington, the Seboeis River near Shin Pond, and the North Branch Penobscot near Pittston Farm.

The highest flows in the basin typically occur in April and May and lowest flows occur in August and September (Table 2). The mean annual flow measured at Veazie, the lowest station on the river with long-term data, is 14,000 cfs (Table 2); however, flows have ranged from a maximum of 154,000 cfs in 1923 to a minimum of 2,500 cfs in 1987.

Total useful water storage in the Penobscot basin is two billion cubic meters (1.6 million acre-feet) with approximately 80% located in the West Branch Penobscot, 10% in the East Branch, and 7% in the Piscataquis River (Baum 1983). Brookfield Power controls multiple water storage facilities in the West Branch Penobscot for power generation. On the East Branch Penobscot, the Maine Department of Conservation (MDOC) owns and controls Telos Dam on Telos Lake and Lock Dam on Chamberlain Lake, and Matagamon Lake Association, Inc. owns and operates the Matagamon Dam. On the Piscataquis River, Ampersand Sebec Lake Hydro LLC owns and operates Sebec Lake Dam, MDOC owns the Seboeis Lake Dam, and the Schoodic Lake Association owns the Schoodic Lake Dam.

The flows at several locations in the Penobscot basin are legally controlled by long-standing agreements and regulatory requirements (FERC 1997). Brookfield Power is required by its charter with the Maine Legislature and current FERC licenses to maintain a minimum flow of 2,000 cfs from the West Branch Penobscot at Millinocket. An agreement between MDIFW and the East Branch Improvement Company mandates a minimum flow of 160 cfs from Grand Lake Mattagamon to the East Branch Penobscot.

Storage capacity and flow requirements in the upper reaches of the basin moderate discharges in the lower river. In general, upstream storage results in increased flows to the downstream areas during low-flow periods and reduced flows during high spring runoff.

Barriers

Man-made barriers have been present throughout the Penobscot basin for over 200 years. Dams were built on tributaries to the estuary in the late 1700s and on the Piscataquis (Sebec Lake, Dover, and Brownville) and Mattawamkeag (Gordon Falls) rivers in the early 1800s. The first mainstem dam was built in the Old Town-Milford area in the mid 1820s, and the last mainstem dam (Mattaceunk) was constructed in 1939.

There are presently 20 federally licensed hydropower projects (27 dams), one surrendered project, one breached dam, at least 102 non-hydropower dams, and thousands of culverts in the Penobscot River watershed. Thirteen of the hydropower dams have upstream fish passage facilities and 10 have a structure or utilize operational measures for downstream passage (Table 3; Figure 3). American eel, American shad, and Atlantic salmon historically utilized portions of the West Branch Penobscot, but the 10 hydropower and water storage dams on the West Branch Penobscot do not pass diadromous fish and no passage is planned in the near term. Six dams in the watershed currently lack upstream or downstream fish passage (Gilman Falls, Orono, Milo, Sebec, Foss Mill, and West Winterport (Table 3). The license exemption for the West Winterport dam has been surrendered, but its status remains uncertain as local opposition precluded dam removal.

Two significant obstacles for migratory fish species are the Veazie and Great Works dams. Removal of these dams will allow Atlantic sturgeon, shortnose sturgeon, rainbow smelt, and Atlantic tomcod free access to the first impassable natural barrier above head of tide, which is believed to be the historical upstream limit for these species. In addition, removal of these dams and improvements to fish passage at Milford and Howland will significantly improve the chances of restoring or enhancing populations of alewife, American eel, American shad, Atlantic salmon, blueback herring, sea lamprey, and striped bass by eliminating or reducing any inefficiency, delay, and mortality associated with fish passage.

Non-hydropower dams and culverts within the Penobscot River basin are currently being mapped on a Geographical Information System by the USFWS. The Lower Penobscot River Stream Barrier Inventory was conducted by the Maine Forest Service in cooperation with the U.S. Fish and Wildlife Service Gulf of Maine Coastal Program during the summer of 2007 to locate barriers to fish passage in tributaries to the Penobscot below the confluences of the Piscataquis and Passadumkeag rivers. Of the 533 crossings surveyed in the lower Penobscot, initial ranking has identified 290 (54%) as severe barriers to aquatic organism passage. Some of these crossings would benefit from better maintenance, such as the 93 blocked by beaver dams or debris. The others, though, represent barriers because of structural deficiencies, the most obvious of which are perched outlets at 205 (38%) of the crossings. Kenduskeag Stream (2003) and the Piscataquis River (2004) were mapped previously. The middle watershed will be surveyed in 2008. Within the next few years these sites will be prioritized and assessed using a standard survey format to determine if they are barriers to fish movement.

Outstanding River Segments

Several river segments within the Penobscot basin are afforded special protection under the Natural Resource Protection Act (NRPA) administered by the Maine Department of Environmental Protection (MDEP). Segments include the mainstem Penobscot between the Veazie and Bangor dams; the East Branch Penobscot from Grindstone Township and East Millinocket to the mainstem; specific sections of the Piscataquis River and some its tributaries including the West Branch Pleasant; and specific sections of the Mattawamkeag River and some its tributaries (38 M.R.S.A. § 480-P).

Additionally, the State's Mandatory Shoreland Zoning Law identifies several significant river segments that are given special shoreland zoning controls designed to protect natural and recreational features. These segments include specific sections of the Mattawamkeag River and some its tributaries; the East Branch Penobscot from Grindstone Township and East Millinocket to the mainstem; and the West Branch Pleasant River (38 M.R.S.A. § 437).

Stream Water Quality Classification and Monitoring
The MDEP has established water quality classifications for state waters ranging from AA (best) to C (worse) (Appendix C). Much of the Penobscot basin is currently classified as B, although many sections of the East Branch, West Branch, and Piscataquis sub basins are classified as A (Figure 4). Class AA water occurs exclusively in a portion of the East Branch and West Branch sub basins. There are two significant reaches that are Class C: 1) West Branch Penobscot from the outlet of Ferguson and Quakish Lakes to its confluence with the East Branch Penobscot River, including all impoundments; and 2) mainstem Penobscot from the confluence of the East Branch and the West Branch to the confluence of the Mattawamkeag River, including all impoundments. Also four tributaries are Class C: Millinocket Stream from the West Branch Canal to its confluence with the West Branch Penobscot; Cambolasse Stream below Rte. 2 and Mattanawcook Stream below outlet to Mattanawcook Pond (both streams in Lincoln) and Kenduskeag Stream (Bangor) below the Bullseye Bridge (38 M.R.S.A. § 467).

A continuous water quality model for the Penobscot River from Millinocket to Bucksport that was developed in 1991 from two prior models is used to determine the state of water quality and the source of water quality impacts. In 1997 and 2001, data were collected in the watershed to assess water quality and update the prior modeling efforts (Albert 2007). The April 2003 modeling report, based on 2001 data, indicated that Class C and Class SC segments were expected to meet minimum dissolved oxygen criteria, but that approximately 51 river miles were not expected to meet Class B criteria (Albert 2007). Additional data, being collected in 2007, will be used with 1997 and 2001 data to calibrate and verify the water quality model, and an updated modeling report will be issued by MDEP.

The Penobscot Nation Water Resources Program (PNWRP) has been collecting water quality data since 1990 to evaluate compliance of industrial discharges and hydropower facilities with water quality regulations, gain information for permit review and re-licensing, support legislative upgrades to water quality classification, and assess the protection of tribal resources by existing regulations (PNWRP 2001). The data collected include temperature, dissolved oxygen, biological oxygen demand, bacteria, color, total suspended solids, turbidity, Secchi disk, transparency, foam, and conductivity. The

PNWRP conducts sampling at more than 80 sites in Penobscot River basin from Dolby Pond in the West Branch Penobscot to Old Town on the mainstem and more than 30 sites on tributaries. These data show that dissolved oxygen and bacteria standards are generally met in this area with the exception of the deeper portions of Dolby Pond and some of the tributary stations, and confirm the occurrence of episodic algae blooms (PNWRP 2001). Katahdin Paper Company's recent decision to stop using phosphoric acid as a whitening agent in paper manufacturing may prevent future occurrences of large algal blooms (Miller 2007).

Point Source Discharges

There are 201 licensed point source discharges in the Penobscot River basin (Figure 5) of which 159 are active outfall pipes or active Combined Sewer Overflows that are associated with treatment facilities licensed under the National Pollution Discharge Elimination System (NPDES). More than half of the NPDES permits are for major point sources that are licensed to discharge more than one million gallons of wastewater a day (Figure 5). The remaining 41 point sources are overboard discharges that are licensed by the State of Maine.

Posted fish consumption advisories

The waters of the Penobscot River basin currently are posted with fish consumption advisories for dioxin, PCBs, mercury or all three pollutants (Figure 6; PNWRP 2001). Mercury consumption advisories are in place for all freshwater fish caught in Maine (Maine CDC 2008). In addition, the lower 57 miles of the Penobscot River, which includes the Indian Island portion of the PIN Reservation, are posted with an advisory for dioxin and coplanar PCBs. In Penobscot Bay and estuary this advisory applies to lobster tomalley.

The U.S. Environmental Protection Agency (EPA) first detected dioxin in Maine in 1984 as a result of a national dioxin survey. By 1987 there was a health advisory in effect on the Penobscot River (PNWRP 2001). A 1988 study of paper mills by EPA found levels of 32 ppq of dioxin associated with Lincoln Pulp and Paper discharges to the Penobscot River. From 1988 to the present the Maine Dioxin Monitoring Program and the PIN have been monitoring dioxin levels in fish tissues of the Penobscot River. State health advisories regarding dioxin levels in Penobscot River fish have been updated periodically and coplanar PCBs were added to the advisory in the late 1990s.

In 1999 the tissue of smallmouth bass and white suckers collected from South Lincoln, Milford, and Veazie were found to exceed the Fish Tissue Action Levels for human consumption (PNWRP 2001). South Lincoln and Milford are four miles and 34 miles downstream, respectively, of the Lincoln Pulp and Paper Company bleached kraft mill. Veazie is approximately 8 miles below the Fort James bleached kraft mill in Old Town, which closed in 2006.

Other environmental issues

Approximately 10 acres of the river bottom where sturgeon over winter along the Bangor Waterfront are covered with coal tar, thought to be the legacy of the former

Bangor Gas Works (now the site of Shaw's Supermarket and Second Street Park). There were other potential sources along the waterfront, including two tar distribution facilities at Dunnett's Cove. The tar deposit is said to be eroding slowly, but on hot days tar may bubble to the surface and an oily sheen may be visible (PEARL 2007).

The HoltraChem facility in Orrington used mercury to make chlorine and other chemicals for the paper industry, which was stored on the site. Concentrations of mercury found in Penobscot River sediments from Frankfort Flats and Fort Point Cove were above 0.15 ppm, levels that can have an adverse affect on bottom-dwelling organisms. Concentrations as high as 4.6 ppm have been found in Frankfort Flats (Livingston 2000). Lobsters caught near Verona Island and Fort Point Cove in the mid-1990s had the highest levels of tomalley mercury in Maine (PEARL 2007).

The legacy of the river's lumbering history has resulted in a layer of wood chips between Winterport and Orland that are re-suspended during the spring freshet (Wippelhauser, MDMR, pers. com). It was common for mills along the river and its tributaries to dump sawdust, edgings and bark into the water (Cutting 1959). The sawdust, fine and light, traveled down to the estuary, where the back-and-forth mixing of the tides forced fine particles to settle out. The sawdust formed a soft carpet of decomposing wood particles up to two feet thick in some tidal flats (Meister 1958).

Fishes of the Penobscot River Basin

At least 86 species of fish inhabit the Penobscot River basin (Baum 1983). Thirty-five are found in marine or estuarine waters, 33 occur in freshwater, five species tolerate a range of salinities, and 12 are diadromous species that migrate between marine and freshwater habitats (Table 4). All of the fishes are native to Maine with the exception of eight freshwater species. Since 1983, black crappie, green sunfish, largemouth bass, and northern pike have been illegally introduced into the Penobscot basin. Brown trout, an exotic species native to Europe, is stocked by MDIFW for recreational fishing. Chain pickerel and smallmouth bass, managed by MDIFW as sportfish, were introduced into Maine waters in the 1800s and have been spread legally and illegally throughout the basin. Landlocked salmon and white perch are native to the Penobscot basin, but their range has been artificially expanded. This management plan focuses on the restoration of native diadromous fishes, which are all currently at less than 1% of historic levels.

Status of Stocks

Atlantic Salmon

Most adult Atlantic salmon returns to the United States occur in Maine, with the Penobscot River accounting for 70.5% of the USA's total returns in 2006 (U.S. Atlantic Salmon Assessment Committee 2007). The dominance of the Penobscot River in U.S. Atlantic salmon adult returns was likely not the case historically, with commercial harvests in the Kennebec River exceeding those in the Penobscot in the late 1800's (Saunders et al. 2006). However, in the early 1970s the number of adult returns to the Penobscot River eclipsed those from other Maine and New England rivers (Figure 7).

On the Penobscot River, the majority of the returns are from hatchery-reared smolts point stocked at various locations in the mid to lower river (Figure 8). Like almost all Atlantic salmon populations in the world (ICES 2007), adult returns (Figure 7) and marine survival as measured by smolt to adult return rate has been declining (Figure 9). The majority of salmon return to the Penobscot River as two sea-winter (2SW) salmon followed by 1SW (grilse) and 3SW salmon. For hatchery-reared smolts released in the Penobscot River in 2004, total home water returns for the cohort (1SW returns in 2005 plus 2SW returns in 2006 plus 3SW returns in 2007) was 0.16% with 2SW salmon returning at a rate of 0.12% (Figure 9).

Atlantic salmon populations in the Penobscot River are supported by two USFWS hatcheries, Craig Brook and Green Lake. Approximately 600,000 smolts, 1.5 million fry and 300,000 parr (Figure 10) have been stocked annually since 1993. Fish are stocked in the mainstem and tributaries upstream from the Veazie Dam including the Piscataquis River, Mattawamkeag River, the East Branch Penobscot River, and the mainstem of the Penobscot River. Fry and parr are distributed in smaller headwater tributaries, whereas smolts are typically stocked in larger tributaries and the mainstem.

Conservation Spawning Escapement (CSE) goals are based on research by Elson (1975) indicating that 2.4 eggs/m^2 are needed to adequately populate a river with juvenile salmon. For the Penobscot River, there is an average fecundity of 7,200 eggs/female (Baum and Meister 1971; Baum 1997a) and a 1:1 sex ratio for multi sea winter aged salmon (Baum 1997a), resulting in a calculated CSE density of one mated pair of salmon per 3,000 m^2 of rearing habitat. Based on original habitat surveys by Cutting (1963), and more recent re-surveys of some reaches, the total CSE for the Penobscot River is estimated at 7,600 salmon (3,800 females: 3,800 males). Meeting or exceeding spawning escapement, with a surplus for mortality and harvest, is the established planning goal (Baum 1997b). The CSE represents the number of successful spawners required drainage-wide, and does not incorporate a surplus for losses due to predation, harvest, etc.

The Gulf of Maine Distinct Population Segment (DPS) of Atlantic salmon was declared endangered by the USFWS and NOAA Fisheries (collectively referred to as the Services) in December 2000 (65 FR 69459). The USFWS and NOAA Fisheries have joint responsibility for recovery of the endangered Gulf of Maine DPS of Atlantic salmon. In December 2005, the Services finalized the Recovery Plan for the Gulf of Maine DPS of Atlantic Salmon (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2005). Atlantic salmon in the lower Penobscot River and its tributaries (below the old Bangor Dam) are part of the DPS. Atlantic salmon upstream of the old Bangor Dam are not designated as an endangered population and are managed under the 2005 ATS 2015: Maine Atlantic Salmon Commission’s 10-Year Strategic Plan (Atlantic Salmon Commission 2005).

The Atlantic Salmon Commission, through collected data and the use of a technical risk assessment, determined that re-opening a restricted catch-and-release recreational fishery in the fall of 2006 would not jeopardize recovery of Atlantic salmon. The fly fishing only season was conducted for one month (September 15 - October 15) in the fall after the annual broodstock collection program was completed, and when cool river temperatures were assured to reduce the risk of angling induced mortality. Angling was limited to a restricted zone below the Veazie Dam. The fall fishery also took place in 2007. One Atlantic salmon was hooked and released in 2006 and two salmon were hooked and released in 2007.

The restoration strategies for Atlantic salmon include the identification and remediation of threats to Atlantic salmon habitat and populations. This includes improving fish passage, optimizing habitat utilization and wild smolt production, identifying opportunities for habitat improvement and increasing the effectiveness of stocking programs. Identifying opportunities to utilize aquaculture in restoration programs can assist in restoration.

American shad

Historically American shad were abundant and widely distributed in the Penobscot River watershed. Maine's first Commissioners of Fisheries reported that American shad had once been the most abundant fish in the Penobscot in terms of biomass, and had supported a valuable commercial fishery (Foster and Atkins 1868a). Estimated annual yields of 2 million adult shad occurred prior to construction of the mainstem dams. Historically, shad ascended as far upstream as the mouth of Wassataquoik Stream on the East Branch Penobscot and near North Twin Lake (Grand Falls or Shad Pond) on the West Branch Penobscot (Foster and Atkins 1868b; Atkins 1870). They were once abundant in the Eastern (Orland) River, Pushaw Stream, Passadumkeag River, and Piscataquis River (Foster and Atkins 1868a), but their historical range in these tributaries is undocumented. Archaeological evidence does show that indigenous people harvested and consumed American shad along the Sebec River in Milo approximately 8,000 years ago (Spiess 1990 unpublished paper). By 1872, the towns of Howland, Milo, Sebec, Dover, Foxcroft, Brownville, and Mattawamkeag were demanding the restoration of salmon, shad, and alewives to their rivers (Stillwell and Stanley 1872).

More recently the Penobscot River American Shad Working Group (PRASWG) estimated total production potential for the Penobscot basin to be 1.56 million adult American shad[1] (PRASWG 2001). This estimate was derived by multiplying a unit production of 2.75 adult American shad per 100 m^2 surface area by the surface area of assumed or known historical habitat in the Penobscot watershed (Table 5; Figure 11; Appendix D). Flagg's (1984) estimate of 1.475 million shad was slightly lower, because it did not include historical habitat in the West Branch Penobscot and the East Branch Mattawamkeag (Table 5). This plan includes the latter two reaches, although the West Branch Penobscot is not targeted for restoration at this time (PRASWG 2001).

[1] Estimates were not made for small tributaries including Kenduskeag Stream, Blackman Stream, Great Works Stream, Sunkhaze Stream, Olamon Stream, Mattamiscontis Stream, Seboeis Stream, Schoodic Stream, and Sebec River.

A remnant population of American shad exists in the Penobscot watershed below the Veazie Project, but adults are rarely observed in the Veazie Dam salmon trap (Dube, MDMR, pers. comm.) and their ability ascend the vertical slot fishway is unknown. In 2004, 12 juvenile American shad were electrofished downstream of the Veazie Dam but none were captured during extensive upriver sampling (mainstem Penobscot from Veazie to the confluence of the East and West Branch in East Millinocket, the West Branch Penobscot to the outlet of Seboomook Lake, the East Branch Penobscot to Grindstone Falls, the Piscataquis River, the Stillwater River, Passadumkeag Stream, Pushaw Stream, and Millinocket Stream) (Yoder et al. 2004). American shad were captured in 1.2 - 8.1% of the stations sampled in the Penobscot estuary during NOAA's Postsmolt Trawl Survey (Sheehan 2003, 2004, 2005).

Management of American shad in Maine must comply with the Atlantic States Marine Fisheries Commission (ASMFC) Amendment 1 and Technical Addendum I to the Fishery Management Plan for American Shad and River Herring (ASMFC 1985; ASMFC 1988). Objectives of the plan are to 1) regulate exploitation to achieve fishing mortality rates sufficiently low to ensure survival and enhancement of depressed stocks and the continued well-being of stocks exhibiting no perceived decline; 2) improve habitat accessibility and quality in a manner consistent with appropriate management actions for non-anadromous fisheries; 3) initiate programs to introduce alosid stocks into waters that historically supported but do not presently support natural spawning migration, expand existing stock restoration programs, and initiate new programs to enhance depressed stocks; and 4) recommend and support research programs that will produce data needed for the development of scientifically rigorous management recommendations relating to sustainable and acceptable yields, the preservation of acceptable stock levels, and optimal utilization of those stocks.

Exploitation of American shad is regulated by MDMR in compliance with the ASMFC interstate management plan. American shad can be taken in Maine's coastal waters only by hook and line, and the possession limit is two fish per person per day. Although there is no directed commercial harvest of American shad in Maine waters, some are taken as bycatch in other fisheries. In the past five years, bycatch in state waters decreased after Maine closed nearshore waters to the commercial harvest of all groundfish species during the months of April, May, and June, and ocean bycatch of American shad has decreased due to increases in the minimum gill net mesh size allowed in the groundfish gill net fishery (Brown, MDMR, pers. comm.).

Currently the lack of access to and from spawning habitat above the Veazie Dam remains the greatest impediment to restoration of American shad to its former distribution and abundance in the Penobscot basin. Removal of the Veazie and Great Works dams, construction of a fish lift at Milford Dam, and construction of an innovative experimental fish bypass at Howland will make approximately 97% of the historic shad habitat above Veazie Dam available (Figure 12) assuming shad can utilize existing upstream passage at the West Enfield and Mattaceunk dams. At full restoration, approximately 1.5 million adults would need to be passed at the Milford Project and 245,000 would need to be passed at the Howland Dam.

Restoration of the American shad population can be accomplished by allowing adults to pass upstream and spawn naturally; trucking adults to specific river reaches and allowing them spawn naturally, stocking hatchery-reared fry or fingerlings in the river or some combination of these measures. Relying on natural reproduction to achieve a population of 1.56 million adults could take more than 50 years, assuming a starting population of 1,000 adults[2] and an optimistic doubling of the population with every generation (5 years). Stocking of hatchery-reared fry has been used successfully on the Susquehanna River, where the ratio of fry stocked to adult returns is 212:1 for the period from 1986-1996 (Hendricks 2003). Stocking of fry has also occurred on the Kennebec, Androscoggin, and Saco rivers and is being initiated on the Merrimack River, but the ratio of adult returns to fry stocked on the Maine rivers is not known.

Alewife

Similar to American shad, alewives were historically very abundant and widely distributed in the Penobscot River watershed. Ford (1882) reported that in 1795 the salmon, shad, and alewives were abundant; in 1805 the Penobscot in Milford "fairly swarmed with the finest fish—salmon, shad and alewives were taken in quantities that now seem almost incredible"; and a single seine haul at Bangor in May 1827 took 7,000 shad and 100 barrels of alewives. Atkins (1887) stated there were no insurmountable natural obstacles to the ascent of alewives on the main river for 193 km (120 miles) from the sea and for nearly the same distance in some of the tributaries; however, elsewhere in the report he stated that according to tradition, alewives reached a point 200 km (124 miles) from the sea on the East Branch Penobscot (i.e., approximately at mouth of Wassataquoik Stream). According to Loring (1880), alewives once ascended the Piscataquis River in immense numbers and were harvested beneath the dam at Dover in 1877 after fish passage was improved at downstream dams (Stillwell and Stanley 1877).

Flagg (1984) estimated total production potential for the Penobscot basin to be 14.56 million adult alewives, which was derived by multiplying 235 adult alewife per surface acre by the surface area of assumed historical lake and pond habitat in the Penobscot watershed (Table 6; Figure 13; Appendix D). The estimate in this plan is higher, because it includes the 40 lakes and ponds identified by Flagg and an additional 11 bodies of water below and 15 above the Veazie Project (Table 6). Both plans include four lakes in the Passadumkeag River drainage above Grand Falls that may not have been accessible to alewives historically (Nicatous Lake, Gassabias Lake, West Lake and Duck Lake), and both use a unit productivity of 235 fish per acre in all habitat

[2] MDMR is assuming that the remnant population is less than 1,000 adults, similar to the size of the remnant population on the Saco River. When upstream passage became available at the lowermost dam on the Saco, the number of American shad passed annually from 1993-1997 was 339-1,053 adults. This first generation represents the best estimate of the size of the remnant population.

regardless of trophic status. Total production for the basin is estimated to be 18.91 million alewives (Table 6).

Wild populations of alewife currently spawn in lakes and ponds below the Veazie Project, and some spawning probably occurs above the Project. Alewives are harvested commercially on the Orland River, were harvested on Souadabscook Stream until 1999, and have been captured in 15.7-53.4% of NOAA's Postsmolt Trawl Survey stations in the Penobscot estuary (Sheehan 2003, 2004, 2005). Adult alewife are often seen in the salmon trap at the Veazie Dam fishway (Dube, MDMR pers. comm.), and MDMR biologists occasionally have received reports of alewives in Pushaw Lake and the Passadumkeag drainage (Flagg pers. comm.). No alewives were captured during a 2004 summer/fall boat electrofishing survey that included the mainstem Penobscot from Hampden to the confluence of the East and West Branch in East Millinocket, the West Branch Penobscot to the outlet of Seboomook Lake, the East Branch Penobscot to Grindstone Falls, the Piscataquis River, the Stillwater River, Passadumkeag River, Pushaw Stream, and Millinocket Stream (Yoder et al. 2004). However, alewives have been taken as bycatch (range: 20-268) in rotary screw traps deployed annually in April and May just below the Veazie Dam (Lipsky, unpublished NOAA data).

Management of alewife in Maine must be in compliance with Amendment 1 and Technical Addendum I to the Fishery Management Plan for American Shad and River Herring (ASMFC 1985; ASMFC 1988). Objectives of the plan are to 1) regulate exploitation to achieve fishing mortality rates sufficiently low to ensure survival and enhancement of depressed stocks and the continued well-being of stocks exhibiting no perceived decline; 2) improve habitat accessibility and quality in a manner consistent with appropriate management actions for non-anadromous fisheries; 3) initiate programs to introduce alosid stocks into waters that historically supported but do not presently support natural spawning migration, expand existing stock restoration programs, and initiate new programs to enhance depressed stocks; and 4) recommend and support research programs that will produce data needed for the development of scientifically rigorous management recommendations relating to sustainable and acceptable yields, the preservation of acceptable stock levels, and optimal utilization of those stocks. Recent declines of alewife populations in some regions prompted the species to be placed on the NOAA-Fisheries Species of Concern list in 2006 (71 FR 61022).

The alewife is still commercially harvested in Maine, primarily by municipalities with alewife rights. Each municipality must submit an annual harvest plan for approval by the Commissioner of MDMR and a harvest report at the end of the fishing season.

The lack of access to and from spawning habitat above the Veazie Dam remains the greatest impediment to restoration of alewife to its former distribution and abundance in the Penobscot watershed. Approximately 86% of alewife spawning habitat is currently above 4-6 dams. Removal of the Veazie and Great Works dams, construction of a fish lift at Milford Dam, and construction of an innovative experimental fish bypass at Howland will place 82% of the habitat above 2-3 dams (Figure 14).

Releasing adults into a waterbody, and allowing them spawn naturally can accomplish restoration of an alewife population to historic habitat. MDMR has restored populations in numerous watersheds by stocking adult alewives at a rate of six fish per acre for a minimum of four years (e.g., MDMR 2006). For this plan we are assuming that the remnant population imprinted to waters above Veazie is less than 10,000 adult fish[3]. Broodstock may have to be obtained from the Orland River, Souadabscook Stream, or Silver Lake to meet stocking needs for larger waterbodies (Table 6).

Blueback herring

The historical distribution and abundance of blueback herring throughout Maine is not well documented, as fisherman did not care for the excessive fattiness that made the species difficult to cure (Atkins 1887). Although blueback herring are externally nearly indistinguishable from alewife, they are more like American shad in their spawning habitat, utilizing rivers and streams rather than lakes and ponds. This plan assumes that the historical distribution of blueback herring is represented by the historical distribution of American shad (Figure 11; PNWRP 2001). The abundance of recently restored blueback herring populations in Maine has not been studied, and there is no estimate of unit production for blueback herring as there is for American shad and alewives. As a result, no estimate of total production for the Penobscot River basin has been made.

A remnant population of blueback herring exists in the Penobscot watershed below the Veazie Dam, but its size and spawning locations are not known. No blueback herring were collected during an extensive boat electrofishing survey that was conducted in summer and fall of 2004 (Yoder et al. 2004). A small number of blueback herring (2 to 62) have been taken annually as bycatch in rotary screw traps deployed just below the Veazie Dam (Lipsky, unpublished NOAA data), and they have been captured in 24.3-60.1% of NOAA's Postsmolt Trawl Survey stations in the Penobscot estuary (Sheehan 2003, 2004, 2005).

Management of blueback herring in Maine must be in compliance with Amendment 1 and Technical Addendum I to the Fishery Management Plan for American Shad and River Herring (ASMFC 1985; ASMFC 1988). Objectives of the plan are to 1) regulate exploitation to achieve fishing mortality rates sufficiently low to ensure survival and enhancement of depressed stocks and the continued well-being of stocks exhibiting no perceived decline; 2) improve habitat accessibility and quality in a manner consistent with appropriate management actions for non-anadromous fisheries; 3) initiate programs to introduce alosid stocks into waters that historically supported but do not presently support natural spawning migration, expand existing stock restoration programs, and initiate new programs to enhance depressed stocks; and 4) recommend and support research programs that will produce data needed for the development of

[3] MDMR is assuming that the remnant population is less than 10,000 adults, similar to the size of the remnant population on the Saco River. When upstream passage became available at the lowermost dam on the Saco, the number of alewife passed annually from 1993-1996 was 883-9,820 adults. This first generation represents the best estimate of the size of the remnant population.

scientifically rigorous management recommendations relating to sustainable and acceptable yields, the preservation of acceptable stock levels, and optimal utilization of those stocks. Recent declines of blueback herring populations in some regions prompted the species to be placed on the NOAA Fisheries Species of Concern list in 2006 (71 FR 61022).

There is no directed commercial or recreational harvest of blueback herring in Maine waters. However, blueback herring are sometimes taken as bycatch in other fisheries.

Restoration of blueback herring in the Penobscot River basin can be accomplished by allowing adults to migrate upstream and spawn naturally. Following removal of Edwards Dam on the Kennebec River, blueback herring quickly established spawning sites in the newly accessible habitat (Wippelhauser 2003).

American eel

Atkins (1887) described the early fisheries for American eel in general terms, but provided no information on the historic distribution and abundance of this species in the Penobscot River basin. No doubt the American eel historically was more abundant and widely distributed than it is today. In 1996 the upstream range of American eel in the basin was documented using data compiled from MDIFW fish population surveys (MDMR and MDIFW 1996), although most of the records were more than 20 years old at the time (PNWRP 2001). Those data indicated that American eels were found throughout the drainage (PNWRP 2001). During a summer and fall boat electrofishing survey conducted in 2004, American eel were collected in the mainstem Penobscot from Hampden to the confluence of the East and West Branch in East Millinocket, in the West Branch Penobscot, the East Branch Penobscot, the Piscataquis River, the Stillwater River, Passadumkeag River, Pushaw Stream, and Millinocket Stream (Yoder et al. 2004). These data show that the catch-per-unit effort (CPUE) of young-of-year (<10 g) and juvenile (10-500 g) eels above the breached Bangor Dam was dramatically less than the CPUE below the dam (Figure 15; data from Yoder et al. 2004)

Management of American eel in Maine must be in compliance with the Interstate Fisheries Management Plan for American Eel (ASMFC 2000). Objectives of the plan are to 1) improve knowledge of eel utilization at all life stages through mandatory reporting of harvest and effort by commercial fishers and dealers and enhanced recreational fisheries monitoring; 2) increase understanding of factors affecting eel population dynamics and life history through increased research and monitoring; 3) protect and enhance eel abundance in all watersheds where eel now occur; 4) where practical restore American eel to those waters where they had historical abundance but now may now be absent by providing access to inland waters for glass eel, elvers, and yellow eel and adequate escapement to the ocean for pre-spawning adult eel; and 5) investigate the abundance level of eel at the various life stages necessary to provide adequate forage for natural predators and support ecosystem health and food chain structure.

On May 27, 2004 the ASMFC requested that the USFWS and NOAA conduct a status review of the American eel, because of concerns about extreme declines of the species in the St. Lawrence-Lake Ontario portion of the species' range. The USFWS and NOAA subsequently received a petition, dated November 12, 2004, from Timothy Allan Watts and Douglas Harold Watts, requesting that the American eel be listed as an endangered species under the federal Endangered Species Act. On February 1, 2007, the USFWS announced that after a thorough review of all available scientific and commercial information, it found that listing the American eel as either threatened or endangered was not warranted at the time.

The American eel is harvested in Maine as a young-of-year (glass eel), juvenile (yellow eel) or pre-spawning adult (silver eel). Glass eels are caught in tidal water with fyke nets or dip nets, yellow eels are harvested in tidal water and freshwater with baited pots, and silver eels are caught in freshwater with weirs. The Penobscot River basin once supported all these fisheries, but the weir fishery for silver eels has been phased out by legislation.

Upstream and downstream passage for the catadromous American eel is in its infancy, and has been requested at hydropower projects in the United States in just the last decade. The first project in Maine with a fish passage requirement for American eel was the Medway Project, which is located on the West Branch Penobscot (Table 3; Figure 3). Construction of upstream eel passage and implementation of downstream passage measures at Penobscot River projects should enhance eel abundance in the Penobscot basin, and increase escapement of pre-spawning adults to the ocean.

Rainbow Smelt

The historical distribution and abundance of rainbow smelt in the Penobscot River was not described in the early reports of Maine's Commissioners of Fisheries. In a later document, Atkins (1887) reported that the rainbow smelt fishery ranked second in importance to the salmon fishery with the aggregate catch being 266,875 (later stated as 366,875) pounds and valued at $14,579. Most of the smelt were taken by the bag net fishery, which was confined to the Eastern (Orland) River and the mainstem Penobscot from Winterport to Mill Creek in South Orrington and Marsh River in Frankfort; the fishery was conducted both day and night in open water and beneath the ice (Atkins 1887). For this plan, MDMR assumes that the upstream limit of rainbow smelt is at the Milford Dam (Figure 3) where the river gradient increases substantially (Baum 1983).

The Penobscot supported an extensive recreational and commercial bag net and gill net fishery for rainbow smelt in the 1970s. The MDMR estimated the adult population of the Penobscot to be two million fish, comprised of at least five spawning stocks (Squiers et al. 1976), and the annual catch was estimated to be 40,000-60,000 pounds (Baum 1983).

The MDMR management plan for rainbow smelt (Squiers et al. 1976) is now over 30 years old. Since the plan was completed, commercial landings have declined from a peak of 254,800 pounds in 1966 to 62 pounds in 2000. In response to region-wide declines in smelt populations and lack of information about the declines, anadromous rainbow smelt were added to NOAA Fisheries Species of Concern list in 2004 (71 FR 61022). With funding from NOAA, the MDMR is collaborating with state fisheries agencies in Massachusetts and New Hampshire to develop a conservation plan for rainbow smelt over the next five years.

Removal of the Veazie and Great Works dams will make 100% of presumed historic spawning habitat available to rainbow smelt in the Penobscot basin.

Shortnose sturgeon and Atlantic sturgeon

Maine's Commissioners of Fisheries did not report the occurrence of shortnose sturgeon or Atlantic sturgeon in the Penobscot River, but older accounts indicate that native people fished for sturgeon in the river in the late 1600s (Appendix A). Sturgeon remains have been found at the junction of Pushaw and Dead Streams in Alton, the Penobscot River at Old Town and numerous sites in Penobscot Bay. In 1722, Colonel Thomas Westbrook noted the abundance of sturgeon, striped bass and eels near the Penobscot Indians' fort at Indian Island in Old Town. He stated: "The Captives Inform'd me That the most part of the Indians food During the Time of the Seige was Seals which they Caught Dayly Keeping out a party of Men for that Purpose They Also Inform us & do Assert That there is great Quantity's of Sturgeon, Bass and Eels to be Caught Even Close by the Island where Penobscut Fort is." For this plan, MDMR assumes that the historical upstream limit for both shortnose sturgeon and Atlantic sturgeon was the set of falls where the Milford Dam is now located (Figure 3).

Until 2006 the status of shortnose sturgeon and Atlantic sturgeon in the Penobscot River was not known, and the most recent documented capture of a shortnose sturgeon had occurred on June 30, 1978 in Northport (Figure 3) when a specimen was found tangled in the leads of an experimental fish trap operated by MDMR. During a directed survey for shortnose sturgeon in 1994 and 1995 in the Penobscot River, MDMR did not capture any shortnose sturgeon in 408 hours of gillnetting effort. Following reports of sturgeon being seen or caught in the Penobscot in 2005, scientists at the University of Maine (UM) initiated a study to determine the distribution and abundance of Atlantic sturgeon in the Penobscot River. To date they have captured more than 62 shortnose sturgeon and seven Atlantic sturgeon in 1004.39 net hours (Fernandes 2006).

The shortnose sturgeon was listed as endangered on March 11, 1967, and remained on the endangered species list with enactment of the federal Endangered Species Act in 1973. NOAA Fisheries recognizes Maine shortnose sturgeon as one of the 19 distinct population segments (NMFS 1998).

The status of Atlantic sturgeon was initially reviewed in 1998 after the Services received a petition to list this species under the Endangered Species Act. At that time it was determined that listing was not warranted, however it was formally retained as a species of concern. In 2003, a workshop sponsored by NOAA Fisheries and USFWS was held to review the status of the Atlantic sturgeon, and the workshop attendees concluded that some populations seemed to be recovering while others remained depressed. As a result NOAA Fisheries initiated a second status review of the species that was completed in 2006. The Atlantic sturgeon is currently a candidate species, and has been placed on the NOAA Fisheries Species of Concern list (71 FR 61022).

Management of Atlantic sturgeon in Maine must be in compliance with Amendment 1 to the Interstate Fishery Management Plan for Atlantic Sturgeon (ASMFC 1990, 1998). Management objectives of Amendment 1 are to 1) establish 20 protected year classes of females in each spawning stock; 2) close the fishery for a sufficient period of time to reestablish spawning stocks and increase numbers in current spawning stocks; 3) reduce or eliminate bycatch mortality of Atlantic sturgeon; 4) determine the spawning sites and provide protection of spawning habitats for each spawning stock; 5) where feasible, reestablish access to historical spawning habitat for Atlantic sturgeon; and 6) conduct appropriate research as needed, especially to define unit stocks of Atlantic sturgeon.

Removal of the Veazie and Great Works dams will make 100% of presumed historic spawning habitat available to both shortnose sturgeon and Atlantic sturgeon in the Penobscot basin.

Striped bass
The historical distribution and abundance of striped bass in the Penobscot River is not well documented. In 1722, Colonel Thomas Westbrook (Appendix A) noted the abundance of striped bass and other fishes near the Penobscot Indians' fort at Indian Island in Old Town. He stated:

> "The Captives Inform'd me That the most part of the Indians food During the Time of the Seige was Seals which they Caught Dayly Keeping out a party of Men for that Purpose They Also Inform us & do Assert That there is great Quantity's of Sturgeon, Bass and Eels to be Caught Even Close by the Island where Penobscut Fort is."

More than 100 years later, Atkins (1887) reported that striped bass were undoubtedly plentiful in most rivers west of the Penobscot, but there was no indication that the species spawned in the Penobscot as they did in the Kennebec.

Striped bass in the Penobscot River probably are fish from southern populations on a feeding migration, and their abundance may be highly variable. In 2006, a year in which striped bass were plentiful along the entire Maine coast, a total of 1,809 individuals ascended the fishway at the Veazie project (MASC unpublished data).

Management of striped bass in Maine must be in compliance with Amendment 6 to the Interstate Fishery Management Plan for Atlantic Striped Bass (ASMFC 1981; ASMFC 2003). Objectives of amendment 6 to the plan are to 1) manage striped bass fisheries under a control rule designed to maintain stock size at or above the target female spawning stock biomass level and a level of fishing mortality at or below the target exploitation rate; 2) manage fishing mortality to maintain an age structure that provides adequate spawning potential to sustain long-term abundance of striped bass populations; 3) provide a management plan that strives to the extent practical to maintain coastwise consistency of implemented measures, while allowing the State defined flexibility to implement alternative strategies that accomplish the objectives of the FMP; 4) foster quality and economically viable recreation, for-hire, and commercial fisheries; 5) maximize cost effectives of current information gathering and prioritize state obligations in order to minimize costs of monitoring and management; 6) adopt a long-term management regime that minimizes the need to make annual changes or modifications to management measures; and 7) establish a fishing mortality target that will result in a net increase in the abundance (pounds) of age 15 and older striped bass in the population, relative to the 2000 estimate.

Atlantic tomcod and sea lamprey
Neither of these two species was harvested commercially on the Penobscot River in the mid 1800s; therefore, there is no information on their historic distribution and abundance. Atkins (1887) did note that a few tomcod were taken as bycatch in the smelt fishery in the Penobscot. Currently there are no state or interstate fisheries management plans for either species. MDMR assumes that Atlantic tomcod did not historically migrate above the Milford Dam (Figure 3), but that sea lamprey did.

Resident Species
Freshwater resident fishes are an important part of Penobscot River ecosystem. However resident fishes are not an explicit part of this plan, because MDIFW manages them by species or by water body (Table 7). Nonetheless, coordination with MDIFW remains an important component of the plan. MDIFW's Inland Fisheries Management System, found on the web at http://mainegov-images.informe.org/ifw/wildlife/groups_programs/comprehensive_strategy/pdfs/appendix11.pdf, is documented in Appendix 11G of Maine's Comprehensive Wildlife Conservation Strategy (MDIFW 2005). The document describes criteria used by MDIFW in making management decisions and the transformation of those into practice. The set of goals and objectives established for each species are documented in MDIFW's Strategic Plan for Inland Fisheries, which along with several management plans are available for review on the MDIFW website (http://www.maine.gov/ifw/fishing/species/management_plans/index.htm).

Foundation
Lack of access to habitat has been a major contributor to the decline of many species in the basin. Due to their uses for hydropower and other purposes, almost all of the major rivers in the northeast U.S. have numerous dams. This presents an enormous challenge for the resource agencies and other conservation interests who are actively involved in fish restoration efforts, given that dams have greatly reduced the amount and accessibility of spawning and rearing habitat that once was available. There is currently no empirical evidence to support the notion that self-sustaining runs of anadromous fish are possible with passage at multiple dams. Supporting evidence ideally would consist of a stable population maintained solely by the natural reproduction of adult fish that utilize fish passage facilities at multiple dams to migrate upriver to spawning/nursery habitat. In addition, it is expected the number of fish passing a dam to be proportional to the amount of habitat above the dam. A stable population is defined as one where fish abundance varies randomly, but does not display an upward or downward trend over time. A review of American shad restoration

programs on five northeast river systems for supporting evidence of sustainable shad runs with passage at multiple dams, provided the following results. Four river systems (Susquehanna, Connecticut, Merrimack, Saco) have a fish lift at the first dam that appears to be efficient at passing Americans shad. However, on each of these four river systems the population is not stable, and fewer shad pass the second dam than expected on the basis of upstream spawning/nursery habitat. On the fifth river (Androscoggin), very few American shad are able to pass the first dam, which has a vertical slot fishway (Lower Penobscot River Basin Comprehensive Settlement Accord 2004).

In addition, multiple dams on a river cause cumulative impacts to upstream and downstream migrating fish. Even if state-of-the-art fish passage facilities have been built, multiple dams result in attrition in the population as fish attempt to negotiate each structure. Many downstream migrating fish also are injured or killed due to passage through turbines. Multiple dams also increase the risk of predation on upstream and downstream migrating fish, and can alter temperature regimes or cause other physical or chemical changes to occur. With respect to fish communities, dams (particularly those used for hydropower generation) can:

- Block, impede, delay, injure or kill upstream and downstream migrating fish;
- Alter stream and riverine habitats through inundation, dewatering, channelization or filling;
- Alter natural flow regimes and water levels through drawdowns, retained flood flows, diversions, reservoir fluctuations and peaking operations;
- Change water quality, including sediment transport, dissolved oxygen and temperature;
- Reduce overall productivity as a result of modified physical and chemical conditions;
- Modify biological communities by creating environments that are more suitable for certain species, at the expense of others, resulting in diminished biodiversity; and
- Alter opportunities for recreational angling and commercial uses (Lower Penobscot River Basin Comprehensive Settlement Accord 2004).

In addition to lack of access to habitat and the threat posed by dams, land use changes and other human impacts have also contributed to the decline of diadromous and resident fishes. Anthropogenic activities include built structures that disrupt the hydrological process in the system. In Maine, these structures include dams, road crossings, and channel alterations. In addition, land use management activities impact the geomorphological and riparian processes, particularly land clearing for agriculture, development, and timber harvest (Boyer et al. 2003; Malanson 1993; National Research Council 2004). The effects of landscape pattern on species populations depend on the amount of suitable habitat available and small changes in land use can change patterns of suitability (Donovan and Strong 2003).

This plan recognizes the importance of restoring the assemblage of diadromous fish that co-evolved and also promotes the importance of habitat for all species. Historically, when salmon smolts were typically migrating downstream in the Penobscot, large runs of adult alewives, blueback herring, and shad, were gathering in the estuary and commencing their upstream migration. Similarly, as adult salmon began to arrive in the lower river, surviving post-spawn adults from these clupeid runs were moving back downstream through the system to the estuary. Finally, within at least some of the juvenile salmon production reaches of the river, there were large numbers of juvenile alewives, blueback herring, and shad either residing in or moving through these juvenile production reaches, leading to a hypothesis that the multiple species created a prey buffer.

Along with the loss of these potential prey buffers through the 19th century, there was also the intentional introduction of smallmouth bass into the watershed in the late 1860s. This species has now expanded throughout the watershed such that virtually every accessible, suitable habitat reach, including dozens of tributary lakes and ponds, has now been colonized. Numerous other non-native fish species have since been introduced (some intentional, some illegal, some accidental) as well over more recent decades, which has exacerbated the problems associated with changes in community assemblages and food web interactions.

Overall Goal of the Plan
To restore and guide the management of diadromous fish populations, aquatic resources and the ecosystems on which they depend, for their intrinsic, ecological, economic, recreational, scientific, and educational values for use by the public.

Strategic Goals, Objectives and Strategies
There are four strategic goals and associated objectives and strategies associated with *the Strategic Plan for the Restoration of Diadromous Fishes to the Penobscot River*. Fundamental to multi-species management is the recognition that optimizing overall ecosystem productivity may limit the production potential of any individual species.

1. **Goal: Coordinate fisheries management and restoration activities among state and federal fisheries agencies, PIN and stakeholders in order to develop criteria to address management differences that strike an appropriate balance in fish community structure compatible with individual agency and stakeholder objectives.**

    1.1. Objective: Establish an interagency technical committee to manage diadromous fish species.
    - 1.1.1. Strategy: Formalize an MOU between MDMR, MDIFW, PIN, USFWS and NOAA to establish the committee.
    - 1.1.2. Strategy: Technical committee decides upon targets for each species and sub-watershed.
    - 1.1.3. Strategy: Develop criteria that provide guidance for establishing reach specific "highest and best use" where significant management conflicts are anticipated or identified.
    - 1.1.4. Strategy: Develop protocols to evaluate and resolve inter-agency management conflicts not adequately addressed by other components of the plan.
    - 1.1.5. Strategy: Consult annually with PPL and other dam owners on passage issues at their facilities.

    1.2. Objective: Development of the operational plan by the Interagency Technical Committee.
    - 1.2.1. Strategy: Submit the operational plan to stakeholders for review and comment.
    - 1.2.2. Strategy: Develop more refined cost estimates for each strategy.
    - 1.2.3. Strategy: Seek funding for restoration actions.
    - 1.2.4. Strategy: Seek additional resources to carry out the strategic plan.

    1.3. Objective: Formalize a procedure to inform and consult stakeholders regarding existing or proposed management activities.
    - 1.3.1. Strategy: Appoint an Advisory Committee to provide advice to the interagency technical committee.

1.3.2. Strategy: Hold an annual meeting to present program results and progress, discuss potential management responses, and review proposed activities for the ensuing year.
1.3.3. Strategy: Continue to develop new and enhance existing partnerships with stakeholders, which maximize resources available for achieving program objectives.
1.3.4. Strategy: Continue to encourage communication and information exchange with those agencies, regulatory bodies, and organizations having related jurisdictional interests and responsibilities.
1.3.5. Strategy: Develop an active outreach program for the dissemination of information to the media, public, and educational programs.
1.3.6. Strategy: Integrate 1.3.4 with existing outreach activities with other programs in the basin, including but not limited to the Atlantic Salmon Federation, Trout Unlimited, Natural Resource Conservation Service and local conservation commissions.

1.4. Objective: Support regional and international efforts relating to diadromous fish management and research.
1.4.1. Strategy: Participate in regional efforts – Atlantic Coastal Fish Habitat Partnership, New England Joint Venture, ASMFC, US Assessment Committee, Eastern Brook Trout Joint Venture, New England Fish Administrators, and New England Atlantic Salmon Coalition, at both administrative and scientific levels.
1.4.2. Strategy: Participate in international efforts such as the North Atlantic Salmon Conservation Organization and the International Council for the Exploration of the Seas.
1.4.3. Strategy: Develop research priorities at regional and international levels.
1.4.4. Strategy: Support ongoing research at regional and international levels.
1.4.5. Strategy: Work closely with the Atlantic salmon Action Teams.

1.5. Objective: Develop a better understanding of the human dimension of fisheries management through partners.
1.5.1. Strategy: Work with academic institutions to study the economic impacts of restoration of diadromous fish.
1.5.2. Strategy: Work to understand community interest in the river.
1.5.3. Strategy: Monitor and evaluate socio-cultural and economic interactions that contribute to and that occur as a result of ecosystem based fisheries management.
1.5.4. Strategy: Examine appropriate case studies and fisheries research, particularly with emphasis on the human dimension that can provide guidance for ecosystem-based management.
1.5.5. Strategy: Improve communication among government groups.
1.5.6. Strategy: Improve regulatory and management policies.

2. **Goal: Provide safe and effective upstream and downstream passage for diadromous fishes at barriers that restrict access between their historical habitat in the Penobscot basin and the ocean.**

2.1. Objective: Ensure safe and effective upstream and downstream fish passage for target species (Table 8) at the Veazie, Great Works, Milford, Howland, West Enfield, Orono, and Stillwater (Figure 3) projects.
- 2.1.1. Strategy: Support implementation of the Lower Penobscot River Basin Comprehensive Settlement Accord.
- 2.1.2. Strategy: Develop standard operating procedure for Milford.
- 2.1.3. Strategy: Assess the use of automated fish counters at key passage facilities.
- 2.1.4. Strategy: Seek funding to evaluate/improve additional fish passage facilities.
- 2.1.5. Strategy: Strategy: Consult annually with PPL on passage issues at their facilities.

2.2. Objective: Ensure safe and effective upstream and downstream fish passage at the, Mattaceunk, Dover-Foxcroft Lower, Dover-Foxcroft Upper, and Guilford (Figure 3) projects for target species (Table 8) as needed or if stocking begins upriver.
- 2.2.1. Strategy: Review or acquire fish passage efficiency data and license requirements for each species at each project.
- 2.2.2. Strategy: Identify and prioritize passage requirements by site and species.
- 2.2.3. Strategy: Install, modify, or test fish passages needed

2.3. Objective: Provide safe and effective upstream and downstream fish passage at barriers such as non-hydropower dams, box culverts, culverts, and physiological blocks, for target species (alewife, blueback herring, Atlantic salmon).
- 2.3.1. Strategy: Identify barriers and prioritize passage needs by site and species.
- 2.3.2. Strategy: Coordinate with other state and federal agencies and NGOs to use a standard protocol and tracking database.
- 2.3.3. Strategy: Develop a funding strategy for barrier removals.
- 2.3.4. Strategy: Work with MDOT and municipalities on culvert issues.
- 2.3.5. Strategy: Develop plans for remediation of passage deficiencies identified under strategy 2.3.1.
- 2.3.6. Strategy: Install and evaluate (as needed) fish passage measures.
- 2.3.7. Strategy: Encourage creation a Barrier Removal Program in the State.
- 2.3.8. Strategy: Research alternative strategies for access to habitat.
- 2.3.9. Removals
- 2.3.10. Natural like bypasses

2.4. Objective: Restrict upstream passage of objectionable species.
- 2.4.1. Strategy: Evaluate physical or temporal modifications to fishway operation that may selectively restrict passage of undesirable species.

2.4.2. Strategy: Perform risk assessments for non-native species prior to changes at fishways.

2.4.3. Strategy: Work with interagency technical committee, lake associations and other NGOs to resolve passage issues.

3. Goal: Restore and maintain a healthy aquatic ecosystem that conserves native biodiversity, manages or prevents the invasion of non-native aquatic species, increases the natural recruitment of fish, and improves aquatic habitat.

3.1. Objective: Protect and/or restore currently degraded critical spawning, nursery, feeding, and overwintering habitat for diadromous fishes.

3.1.1. Strategy: Identify, map, and prioritize important habitat reaches (spawning, nursery, feeding, and over wintering) in the basin by species.

3.1.2. Strategy: Identify and correct factors that may be reducing species-specific habitat suitability.

3.1.3. Strategy: Provide biological information and recommendations during permitting.

3.1.4. Strategy: Assess geomorphology where needed.

3.1.5. Strategy: Work with NGOs and land trusts to identify opportunities for protection or restoration.

3.1.6. Strategy: Work with state, local and federal agencies to assure protection and enhancement of existing aquatic habitat in the basin.

3.1.7. Strategy: Identify, map and make available to agencies that regulate activities affecting aquatic habitat (discharge permits, road and bridge construction, bank stabilization activities, development proposals, and water withdrawals), the location and importance of spawning and rearing habitat in the basin for the target species.

3.1.8. Strategy: Work with MDEP to assure high water quality in the basin.

3.1.9. Strategy: Work within appropriate regulatory processes to assure adequate instream flows for spawning and rearing habitat of target species.

3.1.10. Strategy: Work within appropriate regulatory processes to maintain low levels of percent fines in prime Atlantic salmon spawning and rearing habitat.

3.1.11. Strategy: Identify and prioritize riparian and aquatic habitat areas impacted by past or ongoing human disturbance, and explore opportunities for restoration.

3.1.12. Strategy: Work with NGOs and land trusts to identify opportunities for protection or restoration.

3.2. Objective: Improve water quality in areas where it is compromised and diminishes species-specific habitat suitability.

3.2.1. Strategy: Work with MDEP to identify actions to improve water quality.

3.2.2. Strategy: Coordinate with PIN's water quality monitoring program.

3.2.3. Strategy: Review or acquire baseline water chemistry data in all critical habitats and assess potential impacts on habitat suitability.

3.2.4. Strategy: Evaluate potential remediation measures and implement corrective measures where feasible.

3.2.5. Strategy: Adapt management strategies to reflect existing or modified habitat suitability.

3.2.6. Strategy: Improve Class A waters to Class AA waters.

- 3.2.7. Strategy: Improve Class C waters on the mainstem Penobscot River below confluence with the Mattawamkeag River to Class B.
- 3.2.8. Strategy: Improve 3rd and 4th order streams designated as Class C to Class B, and 3rd and 4th order streams designated as Class B to Class A.

3.3. Objective: Eliminate conditions that lead to fish consumption advisories for dioxins and PCBs in the mainstem Penobscot River.

- 3.3.1. Strategy: Work with MDEP's Surface Water Ambient Toxics (SWAT) Monitoring Program to continue monitoring for dioxins and PCBs.

3.4. Objective: Work with University researchers and other agencies to develop a better understanding of ecosystem processes and the importance in the restoration of fisheries (hydrology, connectivity, species assemblages, food web interactions, energy flow, and mineral cycles).

- 3.4.1. Strategy: Assess the extent of altered ecosystem processes.
- 3.4.2. Strategy: Develop a matrix of land use and potential ecological impact.
- 3.4.3. Strategy: Develop a better understanding of the drivers of species declines by examining underlying factors.

4. Goal: Rebuild sustainable diadromous fish populations, manage populations of native and naturalized aquatic species, reduce populations of nonnative undesirable species, and maintain/enhance fishing opportunity using adaptive management principles.

4.1. Objective: Increase abundance of diadromous fish populations currently limited by inadequate recruitment or survival.

4.1.1. Strategy: Document the abundance and distribution of alewife, American shad, Atlantic sturgeon, Atlantic tomcod, blueback herring, rainbow smelt, sea lamprey, shortnose sturgeon, striped bass, and sea run brook trout, and brook trout.

4.1.1.1. Conduct an annual beach seine survey for juvenile alewife, American shad, blueback herring, and striped bass as required by ASMFC on other rivers undergoing restoration.

4.1.1.2. Conduct an interagency electro-fishing survey once a year to monitor populations.

4.1.2. Strategy: Construct or adapt models to predict mortality by reach and life stage under various scenarios to determine how to reduce losses.

4.1.3. Strategy: Establish or promote self-sustaining populations of alewife, American shad, Atlantic sturgeon, Atlantic tomcod, blueback herring, rainbow smelt, sea lamprey, shortnose sturgeon, striped bass, and sea run brook trout, and brook trout through re-colonization as accessible habitat increases.

4.1.4. Strategy: Produce and collect sea-run Atlantic salmon for broodstock.

4.1.5. Strategy: Integrate hatchery stocking with strategies to improve habitat.

4.1.5.1. Establish or promote self-sustaining populations of Atlantic salmon in historical habitat by adaptive use of hatchery produced fry, parr, smolts and adults.

4.1.5.2. Increase Atlantic salmon hatchery capacity as needed.

4.1.5.3. Determine the appropriate numbers of juvenile salmon and appropriate life stages to stock at appropriate locations and quantification of smolt production.

4.1.5.4. Pursue a better understanding of the existing genetic stock structure.

4.2. Objective: Understand the long-term implications on the age structure of Atlantic salmon returns.

4.2.1. Strategy: Assess 1-yr vs. 2-yr smolt rearing program for increased rate of grilsification.

4.2.2. Strategy: Assess broodstock management program to understand the role of grilse.

4.3. Objective: Minimize the ecological impact of non-native fishes.

4.3.1. Strategy: Assess the species-specific distribution and potential ecological threats of non-native fish species within the Penobscot basin.

- 4.3.1.1. Classify species-specific threats based on scientific literature to prioritize risk.
- 4.3.1.2. Conduct assessments where the literature fails to provide information.

4.3.2. Strategy: Develop a plan to control the spread of non-natives.

4.3.3. Strategy: Implement prioritized plan based on the threat assessment in 4.4.1.

4.3.4. Strategy: Educate the angling public regarding the ecological threats of non-native and illegally introduced species, and encourage anglers to destroy them when captured.

4.3.5. Strategy: Prohibit angling regulations that protect illegally introduced species such as northern pike and largemouth bass within the Penobscot basin.

4.3.6. Strategy: Codify MIFW/MDMR MOA/MOU regarding objectionable species, especially salmonids.

4.4. Objective: Minimize the occurrence and negative effects of invasive plants, invertebrates, and pathogens.

4.4.1. Strategy: Assess the species-specific distribution and potential ecological impact of invasive species.

4.4.2. Strategy: Develop a plan to control the spread of invasive plants, invertebrates, and pathogens.

4.4.3. Strategy: Implement prioritized plan based on the threat assessment in 4.4.1.

4.4.4. Strategy: Work with MDEP to reduce the spread of invasive species.

4.5. Objective: Continue, expand or establish a long-term program to quantify biological characteristics (age, length, weight, sex ratio, genetic makeup) and trends in distribution and abundance of adult and juvenile diadromous fishes.

4.5.1. Strategy: Model reach-specific recruitment and mortality of diadromous species to assess the relative influence of unique or categorical factors on population size.

4.5.2. Strategy: Monitor adult and juvenile populations of Atlantic salmon.

4.5.3. Strategy: Develop and seek funding for the program.

4.6. Objective: Implement the Conceptual Restoration Monitoring Plan for Fisheries Resources Affected by the Penobscot River Restoration Project (Appendix E; Trial 2006).

4.6.1. Strategy: Work with the Penobscot River Science Steering Committee to develop a monitoring design.

4.7. Objective: Provide recreational and commercial fishing opportunities compatible with species management objectives.

4.7.1. Strategy: Develop permissible take estimates compatible with species-specific management objectives based on best available data.

4.7.1.1. Recognize that escapement above and beyond the limitations of spawning or rearing habitat may play a large ecological role for predators and marine derived nutrients.

4.7.2. Strategy: MFIFW and MDMR meet annually to discuss regulation changes.

4.7.3. Strategy: Monitor impacts of fisheries and modify access as appropriate.

4.7.4. Strategy: Work with municipalities and state agencies to identify and promote access points and opportunities.

4.7.5. Strategy: Increase public support for restoration efforts.

Additional Elements Necessary for Recovery

Research Needs

Stocking Strategies: The effectiveness of stocking practices for all species should be assessed; including timing of stocking, life stages, and stocking density. Evaluate stocking strategies for American shad (passing adults upriver versus stocking hatchery-raised fry). The genetic consequences of stocking need to be evaluated before undertaking a stocking program. This includes population genetic concepts (with basin diversity, appropriate donor stocks, homing fidelity etc. It also must consider the risk of domestication on the population(s).

Habitat Quality: The amount of potential rearing habitat for Atlantic salmon (number of units) is known for the basin, except in smaller tributaries, however, the quality of the habitat has not been assessed. The amount and quality of habitat for most other species in unknown, therefore further assessments and research are required.

Land Use: Connecting land use changes to potential changes in habitat quality within the river system and understanding how those changes affect aquatic resources is important.

Ecosystem Function: There is a need to assess how the river has changed over time. Ecosystem components that changed with European settlement of the Penobscot basin include: the fish community (introduced non-native species, lost diadromous species), aquatic mammals (otter, beaver), predator-prey complexes (fish, birds, and mammals) in physical habitat, hydrology, and riparian vegetation. Further, the role of climate change in altering ecosystem function and the decline of Atlantic salmon need to be explored, as well as the potential benefit to other species such as striped bass.

Holistic Approach: The recovery of the Penobscot River for all species needs to be approached holistically. A further understanding the ecosystem and the role of connectivity among main stems and tributaries and habitat types (rapids, flat waters, runs, riffles, pools), of marine derived and terrestrially derived nutrients, and of the macroinvertabrate and fish communities is needed.

Inter-Specific Interactions: Conduct an exhaustive literature survey and assimilate with findings that are currently being produced in Maine (MDMR, ASC, UM etc.).

Funding

The strategy employed in the past to restore the Penobscot River has traditionally fallen somewhere between active and passive restoration: active in the sense of Atlantic salmon broodstock procurement, but essentially passive with respect to the river itself upstream of the Veazie Dam. Restoration has been seriously under-funded and there is a need to secure appropriate staff and resources to advance restoration – especially post dam removal. There should to be a strategy in place by the time the dams are removed to significantly improve resources for the Penobscot. The operational plans should contain realistic funding needs and options to secure funding.

Goal	Objective	Funding	Source	Timeline			
					Phase 1	Phase 2	
				2008	2009-2012	2012-2032	2023+
Goal 1: Coordinate fisheries management and restoration activities	1.1 Establish an interagency technical committee	$5K annual	Agencies involved	x	x	x	x
	1.2 Develop the operational plan	$10K	Agencies involved	x	x	x	x
	1.3 Formalize a procedure to involve stakeholders	$5K annual	Grants and agencies	x	x	x	x
	1.4 Support regional and international efforts	$5-25K - depends on the level of effort	Grants and the organizations	x	x	x	x
	1.5 Understand human dimension	This work will be completed by collaborative efforts with researchers and other stakeholders - funding levels are unknown at this time	Grants		x	x	x
Goal 2: Provide safe and effective upstream and downstream passage	2.1 Ensure safe and effective upstream and downstream fish passage Veazie, Great Works, Milford, Howland, West Enfield, Orono, and Stillwater	$25M for purchase of Veazie, Great Works, Howland $6-25M for removal of Veazie and Great Works, and naturalistic passage at Howland	Multiple sources		x	x	x
	2.2 Ensure safe and effective upstream and downstream fish passage at Mattaceunk, Dover-Foxcroft Lower, Dover-Foxcroft Upper, and Guilford	$200K per project	Multiple sources		x	x	x
	2.3 Ensure safe and effective upstream and downstream fish passage at non-hydro barriers	$200-300K per dam $10-200K per culvert	Grants, DOT	x	x	x	x
	2.4 Restrict upstream passage of objectionable species	Unknown	Unknown				
Goal 3: Maintain or improve the appropriate natural physical and biotic	3.1 Protect and/or restore habitat	$100K annual	Grants and agencies	x	x	x	x
	3.2 Improve water quality	$100K annual	Grants and agencies	x	x	x	x
	3.3 Eliminate conditions that lead to fish consumption advisories	Unknown	MDEP SWAT and grants			x	x
	3.4 Work with University researchers and other agencies to develop a better understanding of ecosystem processes	This work will be completed by collaborative efforts with researchers and other stakeholders - funding levels are unknown at this time	Grants		x	x	x

Goal 4: Rebuild sustainable diadromous fish populations	4.1 Increase abundance of diadromous fish populations currently limited by inadequate recruitment or survival	$320-370K annual for non salmon $650-700K annual salmon $450K five stocking/broodstock trucks and other equipment costs	Grants and agencies	x	x	x	x
	4.2 Understand the long-term implications on the age structure of Atlantic salmon returns	$100K annual	Grants and agencies	x	x	x	
	4.3 Minimize the ecological impact of non-native fishes	Unknown – need to work with MDEP and MDIFW to determine costs	Grants and agencies	x	x	x	x
	4.4 Minimize the occurrence and negative effects of invasive plants, invertebrates, and pathogens	Unknown – need to work with MDEP and MDIFW to determine costs	Grants and agencies	x	x	x	x
	4.5 Quantify biological characteristics	$100K annual	Grants and agencies	x	x	x	
	4.6 Implement the Conceptual Restoration Monitoring Plan	$3.75M over 5 years	Grants, PPL, Agencies	x	x	x	
	4.7 Provide recreational and commercial fishing opportunities	$25K annual	Grants and agencies	x	x	x	x

Total estimated costs (next 5 years excluding the PRRP):
Annual costs: $2,250,000*
One-time expenses: $450,000
Annual projects costs: $200,000 (passage projects)

* does not include additional hatchery costs

Hatchery Capacity

With the construction/operation of the Green Lake National Fish Hatchery (GLNFH), Atlantic salmon smolt production increased dramatically and so did returns (until marine mortality of North American stocks started to increase in late 1980s). However, even with the investment in hatchery capacity, the number of returning salmon has not come close to providing the total spawning escapement needed to seed the available habitat. While GLNFH is operating at capacity, the number of fry, parr, and smolts needed to make a significant dent in spawning escapement is far from being produced. For example, based on the number of identified habitat units in the drainage (103,000 m^2), up to 10,300,000 fry could be stocked. Currently 1M to 1.5M fry are stocked yearly. At current return rates, the program is only providing 10% of the smolt need. There is also a need to look at the requirements for other species.

Outreach and Education

The socio-economic processes of restoration have not traditionally been researched or addressed fully although a recent effort was attempted to assess these processes in regard to Atlantic salmon (Demont & Associates 2005). A top priority is to attempt to re-engage the public in the recovery efforts in the basin, because apathy is a threat to recovery. The awareness, cooperation and participation of stakeholders, landowners, NGOs, public agencies, municipalities, and the general public are essential for restoration. Programs targeted at re-connecting people to the fish through a better understanding of the life history, habitat needs, economics, and importance to the people of Maine as well as the goals and objectives of recovery are crucial.

Public support is also needed to bolster political support. The role of stakeholders in the communities is to inform state representatives and administrative officials of fish restoration benefits and issues, to educate the public about the need to restore habitat, the challenges associated with restoring fisheries and the broad scope of fish restoration activities and to encourage citizens to inform their Local, State and Federal representatives of their support for fisheries restoration.

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Table 1. Major sub watersheds (HUC 8) in the Penobscot River, Maine with watershed area in square miles and kilometers, the amount of surveyed juvenile Atlantic salmon rearing habitat, and the calculated conservation spawning escapement (CSE) for each.

Subwatershed	Area (mi^2)	Area (km^2)	Surveyed habitat units[1] for Atlantic salmon	Calculated CSE[2]
West Branch	2,131	5,518	--	
East Branch	1,118	2,896	30,000	2,000
Mattawamkeag	1,508	3,906	14,000	1,000
Lower Penobscot	2,381	6,167	33,000	2,200
Piscataquis	1,459	3,779	36,000	2,400
Total	6,466	16,747	112,000	7,600

[1] A unit is $100m^2$, numbers rounded to nearest 1,000 units.
[2] Rounded to the nearest 100 adults.

Table 2. Water discharge data

	Mean monthly flows (cfs)			
Month	1940-1987 Veazie	1903-2005 West Enfield	1903-2005 Piscataquis	1903-2005 East Branch
January	10,000	7,976	307	1,081
February	9,800	7,403	271	1,016
March	12,800	11,000	606	1,523
April	34,300	29,630	2,090	4,844
May	27,100	23,590	1,249	4,816
June	13,000	11,610	469	2,261
July	8,400	7,685	240	1,323
August	7,400	6,434	171	901
September	7,700	6,644	187	979
October	9,300	8,455	397	1,240
November	14,000	11,700	674	1,744
December	13,700	10,720	559	1,559
Annual mean	14,000	11,910	601	1,942

Table 3. Upstream and Downstream Fish Passage Facilities, Penobscot River Drainage.

Subdrainage/Project/Dam	Upstream passage type (year built)	Downstream passage type (year built or initiated)
Penobscot		
Bangor	breached	breached
Veazie	vertical slot (1970)	guidance-behavioral-operational
Great Works	2 Denils (1968)	guidance-behavioral-operational
Milford		
Milford	Denil (1968)	guidance-behavioral-operational
Gilman Falls (water control-no turbines)	none	
West Enfield	vertical slot (1988)	bypass (1988)
Mattaceunk (Weldon)	pool-and-weir (1939)	guidance-behavioral-operational
Stillwater		
Orono	none	none
Stillwater	none	guidance-behavioral-operational
Piscataquis		
Howland	Denil (1965)	guidance-behavioral-operational
Brown’s Mill (D-F Lower)	Denil (1973)	guidance-behavioral-operational (1995)
Moosehead Manufacturing (D-F Upper)	Denil (1973)	none
Guilford Dam	Denil (1972)	none
Milo	none	none
Sebec	none	none
Passadumkeag		
Pumpkin Hill	Denil (1985)	bypass (1985)
West Branch		
Medway	eel ramp	sluice-bellmouth weir
Penobscot Mills		
East Millinocket	none	none
Dolby	none	none
North Twin	LLS and brook trout	none
Millinocket Lake	none	none
Ripogenus	none	none
GLHA Storage		
Ragged Lake	none	none
Caucomgomoc Lake	LLS and brook trout	none
Seboomook Lake	none	none
Canada Falls Lake	Closed	Closed prevent access by yellow perch
Marsh Stream		
Frankfort	Denil	required
Foss Mill	none	none
West Winterport (license surrendered)	none	none

Table 4. Fishes of the Penobscot River basin.
(AFS 2004). D=diadromous, F=freshwater*, M=marine.

Common name	Scientific name	Habit	Status
alewife	Alosa pseudoharengus	D	native
American eel	Anguilla rostrata	D	native
American shad	Alosa sapidissima	D	native
Atlantic salmon	Salmo salar	D	native
Atlantic sturgeon	Acipenser oxyrinchus	D	native
Atlantic tomcod	Microgadus tomcod	D	native
blueback herring	Alosa aestivalis	D	native
brook trout	Salvelinus fontinalis	D	native
rainbow smelt	Osmerus mordax	D	native
sea lamprey	Petromyzon marinus	D	native
shortnose sturgeon	Acipenser brevirostrum	D	native
striped bass	Morone saxatilis	D	native
Arctic char	Salvelinus alpinus	F	native
black crappie	Pomoxis nigromaculatus	F	introduced-intracontinental origin
Eastern blacknose dace	Rhinichthys atratulus	F	native
bridle shiner	Notropis bifrenatus	F	native
brook stickleback	Culaea inconstans	F	native
brown bullhead	Ameiurus nebulosus	F	native
brown trout	Salmo trutta	F	exotic-intercontinental origin
burbot	Lota lota	F	native
chain pickerel	Esox niger	F	native
common shiner	Luxilus cornutus	F	native
creek chub	Semotilus atromaculatus	F	native
creek chubsucker	Erimyzon oblongus	F	native
emerald shiner	Notropis atherinoides	F	introduced
fallfish	Semotilus corporalis	F	native
fathead minnow	Pimphales promelas	F	native
finescale dace	Phoxinus neogaeus	F	native
golden shiner	Notemigonus crysoleucas	F	native
green sunfish	Lepomis cyanellus	F	introduced-intracontinental origin
lake trout	Salvelinus namaycush	F	native
lake whitefish	Coregonus clupeaformis	F	native
largemouth bass	Micropterus salmoides	F	introduced-intracontinental origin
longnose dace	Rhinichthys cataractae	F	native
longnose sucker	Catostomus catostomus	F	native
Northern pike	Esox lucius	F	introduced-intracontinental origin
Northern redbelly dace	Phoxinus eos	F	native
pearl dace	Margariscus margarita	F	native
pumpkinseed	Lepomis gibbosus	F	native
redbreast sunfish	Lepomis auritus	F	native
slimy sculpin	Cottus cognatus	F	native
smallmouth bass	Micropterus dolomieui	F	introduced-interstate origin
white perch	Morone americana	F	native
white sucker	Catostomus commersonii	F	native
yellow perch	Perca flavescens	F	native

Table 4 (continued).

Common name	Scientific name	Habit	Status
American plaice	Hippoglossoides platessoides	M	native
American sand lance	Ammodytes americanus	M	native
Atlantic cod	Gadus morhua	M	native
Atlantic herring	Clupea harengus	M	native
Atlantic mackerel	Scomber scombrus	M	native
Atlantic menhaden	Brevoortia tyrannus	M	native
Atlantic red hake	Urophycis chuss	M	native
Atlantic silverside	Menidia menidia	M	native
capelin	Mallotus villosus	M	native
daubed shanny	Leptoclinus maculatus	M	native
fourbeard rockling	Enchelyopus cimbrius	M	native
grubby	Myoxocephalus aenaeus	M	native
little skate	Leucoraja erinacea	M	native
longhorn sculpin	Myoxocephalus octodecemspinosus	M	native
monkfish (goosefish)	Lophius americanus	M	native
northern pipefish	Syngnathus fuscus	M	native
northern searobin	Prionotus carolinus	M	native
ocean pout	Zoarces americanus	M	native
pollock	Pollachius virens	M	native
radiated shanny	Ulvaria subbifurcata	M	native
rock gunnel	Pholis gunnellus	M	native
sea raven	Hemitripterus americanus	M	native
shorthorn sculpin	Myoxocephalus scorpius	M	native
silver hake	Merluccius bilinearis	M	native
smooth flounder	Pleuronectes putnami	M	native
snakeblenny	Lumpenus lumpretaeformis	M	native
spiny dogfish	Squalus acanthias	M	native
striped searobin	Prionotus evolans	M	native
thorny skate	Amblyraja radiata	M	native
white hake	Urophycis tenuis	M	native
winter flounder	Pseudopleuronectes americanus	M	native
winter skate	Leucoraja ocellata	M	native
windowpane	Scophthalmus aquosus	M	native
wrymouth	Cryptacanthodes maculatus	M	native
ninespine stickleback	Pungitius pungitius	M, F	native
threespine stickleback	Gasterosteus aculeatus	M, F	native
banded killifish	Fundulus diaphanus	M,F	native
fourspine stickleback	Apeltes quadracus	M,F	native
mummichog	Fundulus heteroclitus	M,F	native

**Brook trout, lake trout and Arctic char*
Indigenous to all locations where they occur in the drainage (except lake trout in Millinocket Lake)

- Actively managed (the take of these species is regulated and some are stocked)

Landlocked Atlantic salmon and Rainbow smelt
Both species are indigenous to parts of the drainage but the range within the drainage has been expanded by DIFW introductions. Wherever salmon have been stocked smelt have been introduced to provide forage for salmon.

- Actively managed

White perch
White perch were present in all coastal river drainages up to the first barrier that prevented passage of this species. This species has been introduced throughout the drainage.

- Regulated by IFW in 3 bodies of water within the upper Mattawamkeag drainage.

Chain pickerel
Indigenous to Maine but not to the Penobscot drainage. Was introduced into the drainage and has expanded range to most waters.

- Considered to be a game fish (sought by anglers) but is not managed.

Brown trout
An exotic game fish species introduced and managed by IFW in 1 Penobscot drainage lake.

Rainbow trout
Originally found only in western U.S. and Canada. Has been introduced into many Maine waters and is managed by IFW in some waters. Is being stocked in private ponds in the Penobscot drainage that do not have outlets and are not situated where the fish could escape to the wild. No known wild populations in the Penobscot drainage.

Splake
A brook trout x lake trout hybrid (predominately sterile) introduced and managed by IFW in 4 Penobscot drainage lakes.

Smallmouth bass
Introduced into Maine from southern U.S. waters. Some introductions conducted by IFW. Range has expanded to include many Penobscot drainage waters. The take of smallmouth bass is regulated in the majority of waters where the species has been present for many years but is considered to be an invasive in some drainage waters and is not protected. There have been several illegal introductions in Penobscot drainage waters in recent years.

Largemouth bass
Also introduced into Maine from southern U.S. sources. Is generally included with smallmouth bass regulations under the heading of black bass. Has been recently illegally introduced into some Penobscot drainage waters. Is considered by all agencies to be an invasive and Region F of IFW will attempt to remove all regulatory protection of

this species in the Penobscot drainage with the support of the Penobscot River Fisheries Steering Committee.

Northern pike, black crappie and green sunfish.
All are present as the result of recent illegal introductions into the Penobscot River drainage. Pike and crappie are game fish because anglers seek them but they are considered to be invasive species in the Penobscot and are not regulated.

Goldfish
Can be found in some private ponds in the Penobscot drainage. The IFW has regulatory authority to destroy carp populations in all ponds and has done so in most instances. However, there are some private ponds where carp are present.

Table 5. Production estimates for American shad.

River reach	Length (km)	Production units (100 m2)	Production of adult shad	%	Flagg (1984)
Penobscot mainstem					
Bangor Dam to Veazie Dam	5.31	8,125	22,344	1.4	22,352
Veazie Dam to Great Works Dam	11.91	25,359	69,737	4.5	69,768
Great Works Dam to Milford Dam	3.06	5,214	14,339	0.9	14,345
Milford Dam to West Enfield Dam	40.55	145,658	400,560	25.7	400,733
West Enfield Dam to Mattaceunk Dam	46.50	121,162	333,196	21.4	308,579
East Branch Penobscot					
Mattaceunk Dam to Wassataquoik Stream	47.47	74,304	204,336	13.1	204,425
West Branch Penobscot					
Mattaceunk Dam to Shad Pond	9.80	9,372	25,773	1.7	
Piscataquis mainstem					
Howland Dam to Dover-Foxcroft Lower Dam	60.34	55,804	153,461	9.8	153,529
Dover-Foxcroft Lower to Dover-Foxcroft Upper Dam	0.80	383	1,053	0.1	1,054
Dover-Foxcroft Upper Dam to Guilford Dam	13.35	8,215	22,591	1.4	22,601
Guilford Dam to Monson Junction	12.07	5,426	14,922	1.0	14,927
Pleasant					
Mainstem and East Branch to Lower Ebeemee Pond	31.05	13,734	37,769	2.4	37,784
West Branch to Silver Lake	13.35	5,548	15,257	1.0	15,264
Passadumkeag					
Mouth to Lowell Dam	18.99	9,558	26,285	1.7	26,295
Lowell Dam to Saponic Pond	6.92	4,635	12,746	0.8	12,751
Mattawamkeag					
mouth to Mattawamkeag Lake	117.94	74,816	205,744	13.2	171,204
Grand total		567,313	1,560,111		1,475,611
Total excluding West Branch Penobscot		557,941	1,534,338		

Table 6. Production estimates for alewife.

River/Waterbody	DIFW mgmt	Surface acres	Adult production	%	Stocking	Flagg (1884)
Orland						
Alamoosook Lake		1,133	266,255	1.4	6,798	
Toddy Pond		1,987	466,945	2.5	11,922	
Penobscot						
Silver Lake		630	148,050	0.8	3,780	
Souadabscook						
George Pond		46	10,810	0.1	276	
Hammond Pond		83	19,505	0.1	498	
Hermon Pond		461	108,335	0.6	2,766	
Patten Pond		46	10,810	0.1	276	
Tracy Pond		52	12,220	0.1	312	
Etna Pond		361	84,835	0.4	2,166	
Sedgeunkedunk						
Fields Pond		182	42,770	0.2	1,092	
Brewer Lake		881	207,035	1.1	5,286	
Blackman						
Chemo Pond	WW	1,146	269,310	1.4	6,876	269,310
Parks Pond		124	29,140	0.2	744	29,140
Davis Pond		417	97,995	0.5	2,502	97,995
Pushaw						
Pushaw Lake	WW	5,056	1,188,160	6.3	30,336	1,188,160
Little Pushaw Pond	WW	411	96,585	0.5	2,466	96,585
Mud Pond	WW	366	85,972	0.5	2,195	
Boyd Lake	WW	1,005	236,175	1.2	6,030	
Passadumkeag						
Cold Stream Pond	CW	3,628	852,580	4.5	21,768	
Upper Cold Stream Pond	CW	186	43,710	0.2	1,116	
Eskutassis Pond	WW	876	205,860	1.1	5,256	205,860
Saponac Pond	WW	922	216,670	1.1	5,532	216,670
Madagascal Pond	WW	790	185,650	1.0	4,740	
Number Three Pond	WW	659	154,865	0.8	3,954	154,865
Nicatous Lake	CW	5,165	1,213,775	6.4	30,990	1,213,775
West Lake	CW	1,344	315,840	1.7	8,064	315,840
Duck Lake	CW	256	60,160	0.3	1,536	
Gassabias Lake	WW	896	210,560	1.1	5,376	210,560
Seboeis						
Endless Lake	CW	1,499	352,265	1.9	8,994	352,265
Seboeis Lake	CW	4,201	987,235	5.2	25,206	987,235
Cedar Lake	CW	685	160,975	0.9	4,110	160,975
East Branch Lake	WW	1,122	263,677	1.4	6,732	
Schoodic						
Schoodic Lake	CW	7,168	1,684,480	8.9	43,008	1,684,480
Pleasant						
Ebeemee Lake	WW	940	220,900	1.2	5,640	220,900
Upper Ebeemee Lake	WW	196	46,060	0.2	1,176	46,060
Silver Lake	CW	305	71,675	0.4	1,830	71,675

Sebec						
Sebec Lake	CW	6,803	1,598,705	8.5	40,818	1,598,705
Piscataquis						
Manhanock Pond / Harlow Pond		595	139,825	0.7	3,570	
Kingsbury						
Piper Pond		420	98,700	0.5	2,520	98,700
Mattamiscontis						
Mattamiscontis Lake	WW	1,025	240,875	1.3	6,150	240,875
Little Mattamiscontis Lake	WW	275	64,625	0.3	1,650	64,625
South Branch Lake	WW	2,035	478,225	2.5	12,210	478,225
Penobscot						
Mattanawcook Pond	WW	832	195,520	1.0	4,992	
Crooked Pond	WW	220	51,700	0.3	1,320	
Folsom Pond	WW	282	66,270	0.4	1,692	
Upper Pond	WW	506	118,910	0.6	3,036	
Cambolasse						
Snag Pond	WW	160	37,600	0.2	960	37,600
Center Pond	WW	192	45,120	0.2	1,152	45,120
Cambolasse Pond	WW	211	49,585	0.3	1,266	49,585
Long Pond	WW	153	35,955	0.2	918	35,955
Egg Pond	WW	128	30,080	0.2	768	30,080
Caribou Pond	WW	544	127,840	0.7	3,264	127,840
Mattakeunk						
Silver/Mattakeunk Lake	CW	570	133,845	0.7	3,417	135,360
Molunkus						
Molunkus Lake	CW	1,050	246,750	1.3	6,300	246,750
Plunkett Pond	WW	435	102,225	0.5	2,610	102,225
Flinn Pond	WW	269	63,215	0.3	1,614	63,215
Wytopitlock						
Wytopitlock Lake	WW	1,152	270,720	1.4	6,912	270,720
West Branch Mattawamkeag						
Mattawamkeag/Upper Mattawamkeag Lake	CW	3,330	782,550	4.1	19,980	782,550
Rockabema Lake		339	79,665	0.4	2,034	79,665
East Branch Mattawamkeag						
Pleasant Lake	CW	1,832	430,520	2.3	10,992	430,520
Skitacook Lake		435	102,225	0.5	2,610	102,225
Baskahegan						
Upper Hot Brook Lake		912	214,320	1.1	5,472	
Lower Hot Brook Lake		713	167,555	0.9	4,278	
Crooked Brook Flowage	WW	1,645	386,575	2.0	9,870	386,575
Baskhegan Lake	WW	6,944	1,631,840	8.6	41,664	1,631,840
Mattaceunk						
Mattaceunk Lake	WW	576	135,360	0.7	3,456	
Salmon						
Salmon Stream Lake		659	154,865	0.8	3,954	
Total			18,909,610	100		14,561,305

Table 7. MDIFW cold and warm water management areas and waters by drainage area with management

COLDWATER SPECIES MANAGEMENT WATERS

					STOCKING				WILD POPULATIONS			OTHER SPECIES					COMMENTS
LAKE NAME	LAKE CODE	TOWN	COUNTY	ACRES	BKT	LLS	BNT	SPLAKE	BKT	LLS	LKT	SLT	SMB	LMB	PKL	WHP	
B POND	0478	TB R11 WELS	PISCATAQUIS	644					X								
CEDAR LAKE	2004	T3 R9 NWP	PENOBSCOT	685	X			X				X			X	X	
CEDAR POND	0474	TB R10 WELS	PISCATAQUIS	65					X								
COLD STREAM POND	2146	ENFIELD	PENOBSCOT	3628	X	X					X	X	X		X	X	
COLD STREAM POND, UP.	2232	LINCOLN	PENOBSCOT	685							X	X	X		X	X	
DUCK LAKE	4746	T4 ND	HANCOCK	1222	X	X					X	X					
ENDLESS LAKE	0942	T3 R9 NWP	PENOBSCOT	1499				X		X		X	X		X	X	
GAUNTLET POND	0472	TB R10 WELS	PISCATAQUIS	11					X								
HOUSTON POND, LITTLE	0920	T6 R9 NWP	PISCATAQUIS	27					X								
MATTAKEUNK LAKE	2242	LEE	PENOBSCOT	570	X										X	X	SMB REPORTED
MATTAWAMKEAG LAKE	1686	ISLAND FALLS	AROOSTOOK	3330		X						X	X		X	X	
MEDUNKEUNK LAKE	2132	T2 R9 NWP	PENOBSCOT	67					X								
MIDDLE BRANCH POND	0912	T5 R9 NWP	PISCATAQUIS	34					X								
MOLUNKUS LAKE	3038	T1 R5 WELS	AROOSTOOK	1050		X						X	X		X	X	
NICATOUS LAKE	4766	T40 MD	HANCOCK	5165		X	X					X	X	X	X	X	
PISTOL LAKE, LOWER	4756	T3 ND	HANCOCK	979					X	X		X			X	X	
PISTOL LAKE, MIDDLE	4750	T4 ND	HANCOCK	112					X							X	
PISTOL LAKE, SIDE	4752	T3 & T4 ND	HANCOCK	147	X											X	
PISTOL LAKE, UPPER	4748	T4 ND	HANCOCK	128					X							X	
PLEASANT POND	1728	ISLAND FALLS	AROOSTOOK	1832	X	X						X	X		X	X	
PORTER POND	4760	T3 ND	HANCOCK	58					X								
ROUND POND, LITTLE	2224	LINCOLN	PENOBSCOT	75	X												
SCHOODIC LAKE	0956	LAKEVIEW PLT.	PISCATAQUIS	7168	X	X					X	X	X		X		
SEBEC RIVER	05320	MILO	PISCATAQUIS		X								X		X		
SEBOEIS LAKE	0954	T4 R9 NWP	PISCATAQUIS	4201		X		X				X	X		X	X	

SEBOEIS STREAM	05301	SEBOEIS PLT.	PENOBSCOT		X												
SILVER LAKE	0922	T6 R9 NWP	PISCATAQUIS	305					X								
SPRING POND	4758	T3 ND	HANCOCK	435	X	X						X			X	X	
TITCOMB POND	4582	T32 MD	HANCOCK	38	X												
TROUT POND	4716	LOWELL	PENOBSCOT	20	X												
TROUT POND	4724	GRAND FALLS	PENOBSCOT	15					X								
TURTLE POND	0952	LAKEVIEW PLT.	PISCATAQUIS	81	X												
WEIR POND	4684	LEE	PEN	45	X										X		
WEST LAKE	0503	T3 ND	HANCOCK	1344	X	X						X	X		X	X	

BKT = BROOK TROUT
LLS = LANDLOCKED SALMON
LKT = LAKE TROUT

BNT = BROWN TROUT
SLT = SMELT
SMB = SMALLMOUTH BASS

LMB = LARGEMOUTH BASS
PKL = CHAIN PICKEREL
WHP = WHITE PERCH

WARMWATER SPECIES MANAGEMENT WATERS

LAKE NAME	LAKE CODE	TOWN	COUNTY	WILD BKT	SMB	LMB	PKL	WHP	SLT	COMMENTS
BASKAHEGAN LAKE	1078	BROOKTON	WASHINGTON		X		X	X		
BOYD LAKE	2158	ORNEVILLE	PISCATAQUIS		X		X	X		
CAMBOLASSE POND	2214	LINCOLN	PENOBSCOT		X	X	X	X		
CARIBOU,LONG, EGG POND	2216	LINCOLN	PENOBSCOT		X	X	X	X		
CENTER POND	2218	LINCOLN	PENOBSCOT				X	X		
CHEMO POND	4278	BRADLEY	PENOBSCOT		X		X	X		
CROOKED BROOK FLOWAGE	1082	DANFORTH	WASHINGTON		X		X	X		
CROOKED BROOK LAKE	7393	FOREST TWP.	WASHINGTON		X		X	X		
CROOKED POND	2220	LINCOLN	PENOBSCOT		X		X	X		
DRAKE LAKE	1336	FOREST TWP.	WASHINGTON		X		X	X		
EAGLE LAKE	3090	DREW PLT.	PENOBSCOT							UNSURVEYED
EAST BRANCH LAKE	2130	T3 R9 NWP	PENOBSCOT		X		X	X		
EBEEMEE LAKE	0914	T5 R9 NWP	PISCATAQUIS		X		X	X		LARGEMOUTH BASS REPORTED
EBEEMEE LAKE, UPPER	0966	T4 R9 NWP	PISCATAQUIS		X		X	X		
ESCUTASSIS POND	2250	LOWELL	PENOBSCOT		X		X	X		

ESCUTASSIS POND, LITTLE	2252	BURLINGTON	PENOBSCOT		X		X	X		
FLINN POND	3036	T1 R5 WELS	AROOSTOOK				X			
FOLSOM POND	2222	LINCOLN	PENOBSCOT		X		X	X		
GASSABIAS LAKE	4782	T41 MD	HANCOCK				X	X		
GREEN POND	2256	T3 R1 NBPP	PENOBSCOT	X			X		X	
HOLLAND POND	2150	ALTON	PENOBSCOT							
JACKSON BROOK LAKE	1334	FOREST TWP.	WASHINGTON		X		X	X		
MADAGASCAL POND	2254	BURLINGTON	PENOBSCOT		X		X	X	X	
MADAGASCAL POND, LITTLE	2258	T3 R1 NBPP	PENOBSCOT		X		X	X		
MATTAMISCONTIS LAKE	2140	T2 R9 NWP	PENOBSCOT				X	X		
MATTAMISCONTIS LAKE, LIT	2138	T3 R9 NWP	PENOBSCOT				X	X		
MATTANAWCOOK LAKE	2226	LINCOLN	PENOBSCOT		X		X	X	X	
MATTASEUNK LAKE	3040	MOLUNKUS	AROOSTOOK		X		X	X		
MUD POND	2278	OLD TOWN	PENOBSCOT		X		X	X		
MUD POND	3092	DREW PLT.	PENOBSCOT							UNSURVEYED
NUMBER THREE POND	9635	T3 R1 NBPP	PENOBSCOT		X		X	X		
PICKEREL POND	2152	ALTON	PENOBSCOT				X			
PICKEREL POND	4718	LOWELL	PENOBSCOT				X			
PLUNKETT POND	3056	BENEDICTA	AROOSTOOK		X		X	X		
PUG POND	2154	ALTON	PENOBSCOT				X			
PUSHAW LAKE	0080	OLD TOWN	PENOBSCOT		X		X	X		NORTHERN PIKE
PUSHAW LAKE, LITTLE	2156	HUDSON	PENOBSCOT		X		X	X		
RUSH POND	3062	T2 R6 WELS	PENOBSCOT				X	X		
SALMON STREAM LAKE	3046	T1 R6 WELS	PENOBSCOT		X		X	X		
SALMON STREAM LAKE, LIT	3048	T1 R6 WELS	PENOBSCOT		X		X	X		
SAPONAC POND	4722	GRAND FALLS PLT.	PENOBSCOT		X		X	X		
SNAG POND	2228	LINCOLN	PENOBSCOT		X	X	X	X		
SOUTH BRANCH POND	2144	SEBOEIS PLT.	PENOBSCOT		X		X	X		
UPPER POND	2230	LINCOLN	PENOBSCOT	X				X		
WYTOPITLOCK LAKE	1702	GLENWOOD	AROOSTOOK		X		X	X	X	

SMB = SMALLMOUTH BASS
LMB = LARGEMOUTH BASS
PKL = CHAIN PICKEREL
WHP = WHITE PERCH
SLT = SMELT

WATERS BY DRAINAGE AREA WITH MANAGEMENT TYPE						
DRAINAGE	**TRIB 1**	**TRIB 2**	**LAKE NAME**	**LAKE CODE**	**TOWN**	**MGMT**
VEAZIE TO	BLACKMAN STREAM		CHEMO POND	4278	BRADLEY	WW
PISCATAQUIS RIVER	PUSHAW STREAM		MUD POND	2278	OLD TOWN	WW
			PUSHAW LAKE	0080	OLD TOWN	WW
			PUSHAW LAKE, LITTLE	2156	HUDSON	WW
			PUG POND	2154	ALTON	WW
	BIRCH STREAM		BOYD LAKE	2158	ORNEVILLE	WW
			HOLLAND POND	2150	ALTON	WW
			PICKEREL POND	2152	ALTON	WW
	SUNKHAZE STREAM		TITCOMB POND	4582	T32 MD	CW
	OLAMON STREAM		OLAMON POND	4726	GREENFIELD	NC
	PASSADUMKEAG RIVER	COLD STREAM	COLD STREAM POND	2146	ENFIELD	CW
			COLD STREAM POND, UP.	2232	LINCOLN	CW
			ROUND POND, LITTLE	2224	LINCOLN	CW
			TROUT POND	4716	LOWELL	CW
		ESCUTASSIS STREAM	ESCUTASSIS POND	2250	LOWELL	WW
			ESCUTASSIS POND, LITTLE	2252	BURLINGTON	WW
			PICKEREL POND	4718	LOWELL	WW
		MAIN STEM	SAPONAC POND	4722	GRAND FALLS PLT.	WW
			TROUT POND	4724	GRAND FALLS	CW
		MADAGASCAL STREAM	GREEN POND	2256	T3 R1 NBPP	WW
			MADAGASCAL POND	2254	BURLINGTON	WW
			MADAGASCAL POND, LITTLE	2258	T3 R1 NBPP	WW
	GRAND FALLS					
		NICATOUS STREAM	PISTOL LAKE, LOWER	4756	T3 ND	CW
			PISTOL LAKE, MIDDLE	4750	T4 ND	CW
			PISTOL LAKE, SIDE	4752	T3 ND	CW
			PISTOL LAKE, UPPER	4748	T4 ND	CW
			NICATOUS LAKE	4766	T40 MD	CW
			PORTER POND	4760	T3 ND	CW
			WEST LAKE	0503	T3 ND	CW

			DUCK LAKE	4746	T4 ND	CW
			GASSABIAS LAKE	4782	T41 MD	WW
		SPRING POND BROOK	SPRING POND	4758	T3 ND	CW
		MAIN STEM	NUMBER THREE POND	9635	T3 R1 NBPP	WW
		MAIN STEM	WEIR POND	4684	LEE	CW
PISCATAQUIS RIVER	SEBOEIS STREAM		SEBOEIS STREAM	05301	SEBOEIS PLT.	CW
		WEST BRANCH	ENDLESS LAKE	0942	T3 R9 NWP	CW
			SEBOEIS LAKE	0954	T4 R9 NWP	CW
			TURTLE POND	0952	LAKEVIEW PLT.	CW
		EAST BRANCH	CEDAR LAKE	2004	T3 R9 NWP	CW
			EAST BRANCH LAKE	2130	T3 R9 NWP	WW
	SCHOODIC STREAM		SCHOODIC LAKE	0956	LAKEVIEW PLT.	CW
	PLEASANT RIVER		PLEASANT RIVER	05318	BROWNVILLE JCT	CW
	PLEASANT RIVER	WEST BRANCH	SILVER LAKE	0922	T6 R9 NWP	CW
			HOUSTON POND, LITTLE	0920	T6 R9 NWP	CW
			MIDDLE BRANCH POND	0912	T5 R9 NWP	CW
		EAST BRANCH	EBEEMEE LAKE	0914	T5 R9 NWP	WW
			EBEEMEE LAKE, UPPER	0966	T4 R9 NWP	WW
			B POND	0478	TB R11 WELS	CW
			CEDAR POND	0474	TB R10 WELS	CW
			GAUNTLET POND	0472	TB R10 WELS	CW
	SEBEC RIVER		SEBEC RIVER	05320	MILO	CW
PISCATAQUIS RIVER TO	MATTAMISCONTIS STREAM		MATTAMISCONTIS LAKE, LIT	2138	T3 R9 NWP	WW
MATTAWAMKEAG RIVER			MATTAMISCONTIS LAKE	2140	T2 R9 NWP	WW
			SOUTH BRANCH POND	2144	SEBOEIS PLT.	WW
	MATTANAWCOOK STREAM		MATTANAWCOOK LAKE	2226	LINCOLN	WW
			FOLSOM POND	2222	LINCOLN	WW
			CROOKED POND	2220	LINCOLN	WW
			UPPER POND	2230	LINCOLN	WW
	MEDUNKEUNK STREAM		MEDUNKEUNK LAKE	2132	T2 R9 NWP	CW
	CAMBOLASSE STREAM		SNAG POND	2228	LINCOLN	WW
			CAMBOLASSE POND	2214	LINCOLN	WW
			CARIBOU,LONG, EGG POND	2216	LINCOLN	WW
			CENTER POND	2218	LINCOLN	WW

MATTAWAMKEAG RIVER	MATTAKEUNK STREAM		MATTAKEUNK LAKE	2242	LEE	CW
	MOLUNKUS STREAM		MOLUNKUS LAKE	3038	T1 R5 WELS	CW
			FLINN POND	3036	T1 R5 WELS	WW
			PLUNKETT POND	3056	BENEDICTA	WW
	MAIN STEM	MUD BROOK	MUD POND	3092	DREW PLT.	WW
	MAIN STEM	EAGLE BROOK	EAGLE LAKE	3090	DREW PLT.	WW
MATTAWAMKEAG RIVER	WYTOPITLOCK STREAM		WYTOPITLOCK LAKE	1702	GLENWOOD	WW
	BASKAHEGAN STREAM		CROOKED BROOK FLOWAGE	1082	DANFORTH	WW
			CROOKED BROOK LAKE	7393	FOREST TWP.	WW
			BASKAHEGAN LAKE	1078	BROOKTON	WW
		JACKSON BROOK	JACKSON BROOK LAKE	1334	FOREST TWP.	WW
			DRAKE LAKE	1336	FOREST TWP.	WW
	W.BR.MATTAWAMKEAG		MATTAWAMKEAG LAKE	1686	ISLAND FALLS	CW
	E.BR.MATTAWAMKEAG RIVER		PLEASANT POND	1728	ISLAND FALLS	CW
MATTAWAMKEAG RIVER TO		MAIN STEM	MATTASEUNK LAKE	3040	MOLUNKUS	WW
EAST BRANCH PENOBSCOT	SALMON STREAM		SALMON STREAM LAKE	3046	T1 R6 WELS	WW
			SALMON STREAM LAKE, LIT	3048	T1 R6 WELS	WW
			RUSH POND	3062	T2 R6 WELS	WW
			DAVIDSON POND	3060	HERSEYTOWN	NC

Table 8. Species to be passed at hydropower projects in the Penobscot basin.
Uncertainty about upstream range is indicated by X?.

Species	Milford	West Enfield	Mattaceunk	Howland	Dover-Foxcroft Lower	Dover-Foxcroft Upper	Guilford	Medway
alewife	X	X	X	X	X	X	X	
American eel	X	X	X	X	X	X	X	X
American shad	X	X	X	X	X	X	X	
Atlantic salmon	X	X	X	X	X	X	X	
Atlantic sturgeon								
Atlantic tomcod								
blueback herring	X	X	X	X	X	X	X	
rainbow smelt								
sea lamprey	X	X	X?	X?				
shortnose sturgeon								
striped bass	X?							

Figure 1. Simplified spatial and temporal overlap of diadromous fishes in the Penobscot River ecosystem, where arrows represent peak activity periods. In many cases, movement patterns may be quite complex: for example, adult salmon may enter the river as early as April with a peak in June, dwindling off at the end of June and then another group of adults may move in beginning in August with a peak in September. Shown are rainbow smelt (Osmerus mordax), American eel (Anguilla rostrata), alewife (Alosa pseudoharengus), sea lamprey (Petromyzon marinus), blueback herring (Alosa aestivalis), American shad (Alosa sapidissima), and Atlantic salmon (Salmo salar). Not shown are shortnose sturgeon (Acipenser brevirostrum), Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus), brook trout (Salvelinus fontinalis), Atlantic tomcod (Microgadus tomcod), and striped bass (Morone saxatilis), which would have spawned in the lower Penobscot River, below the first set of falls in Milford, Maine. YOY = young-of-year. Figure modified from Saunders et al. (2006) and information in Collette and Klein-MacPhee (2002).

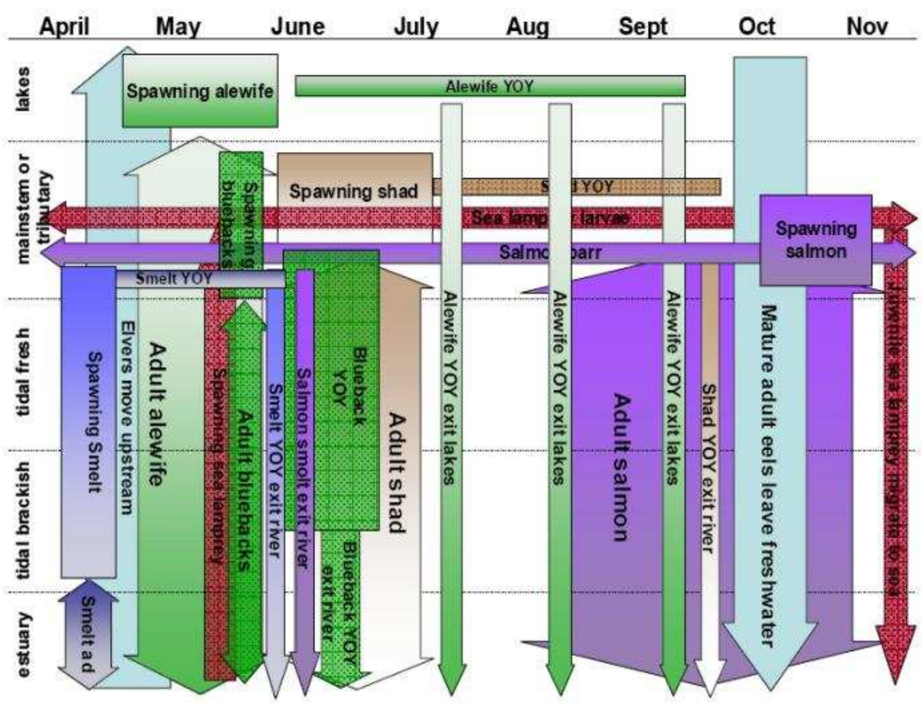


Figure 2 . Penobscot River subwatersheds.

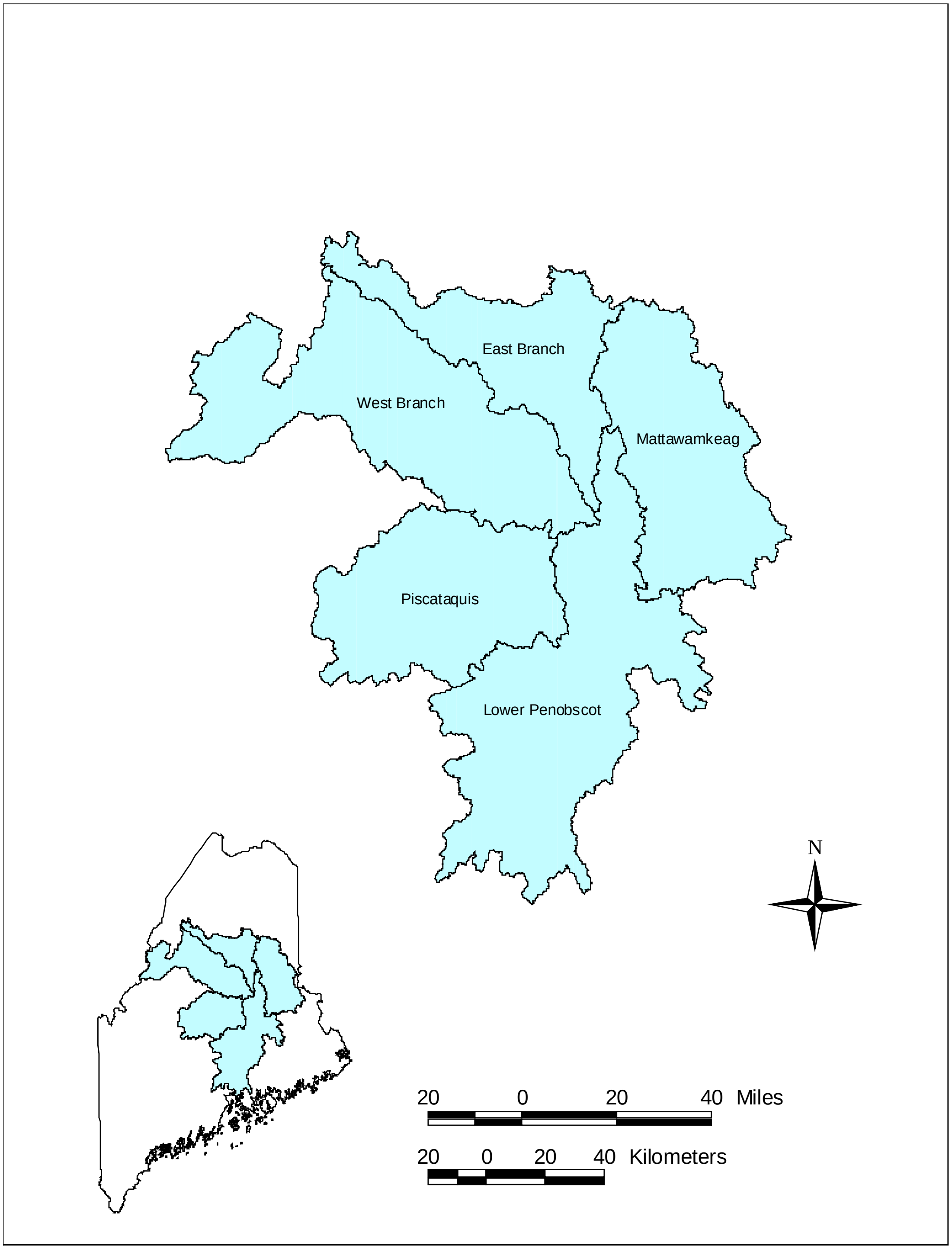


Figure 3. Location of barriers in the Penobscot River basin.
Red dots are hydropower projects, green dots are non-hydropower dams.

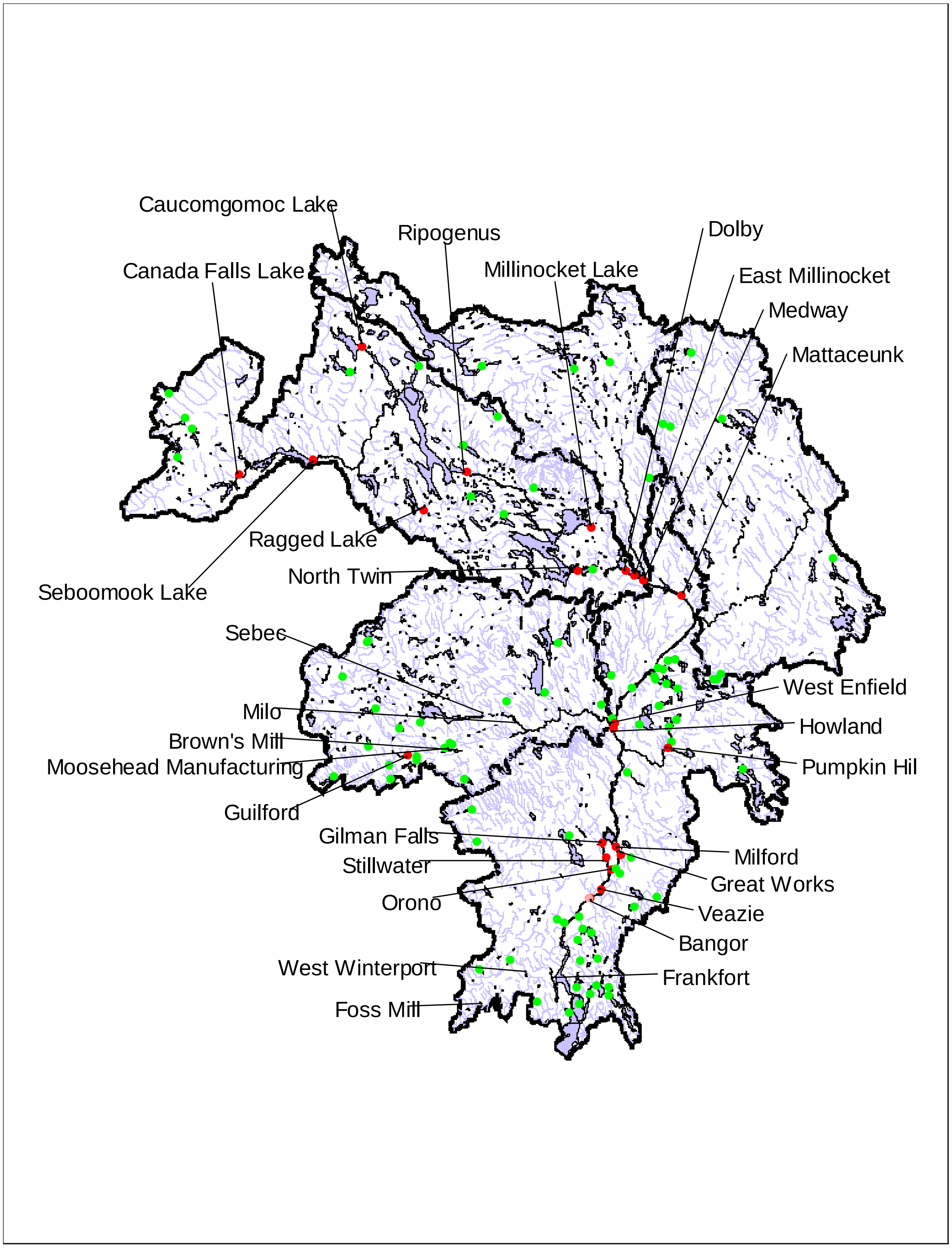


Figure 4. Penobscot Basin water quality.
Class AA=dark blue; Class A = light blue: Class B=gold; Class C=red.

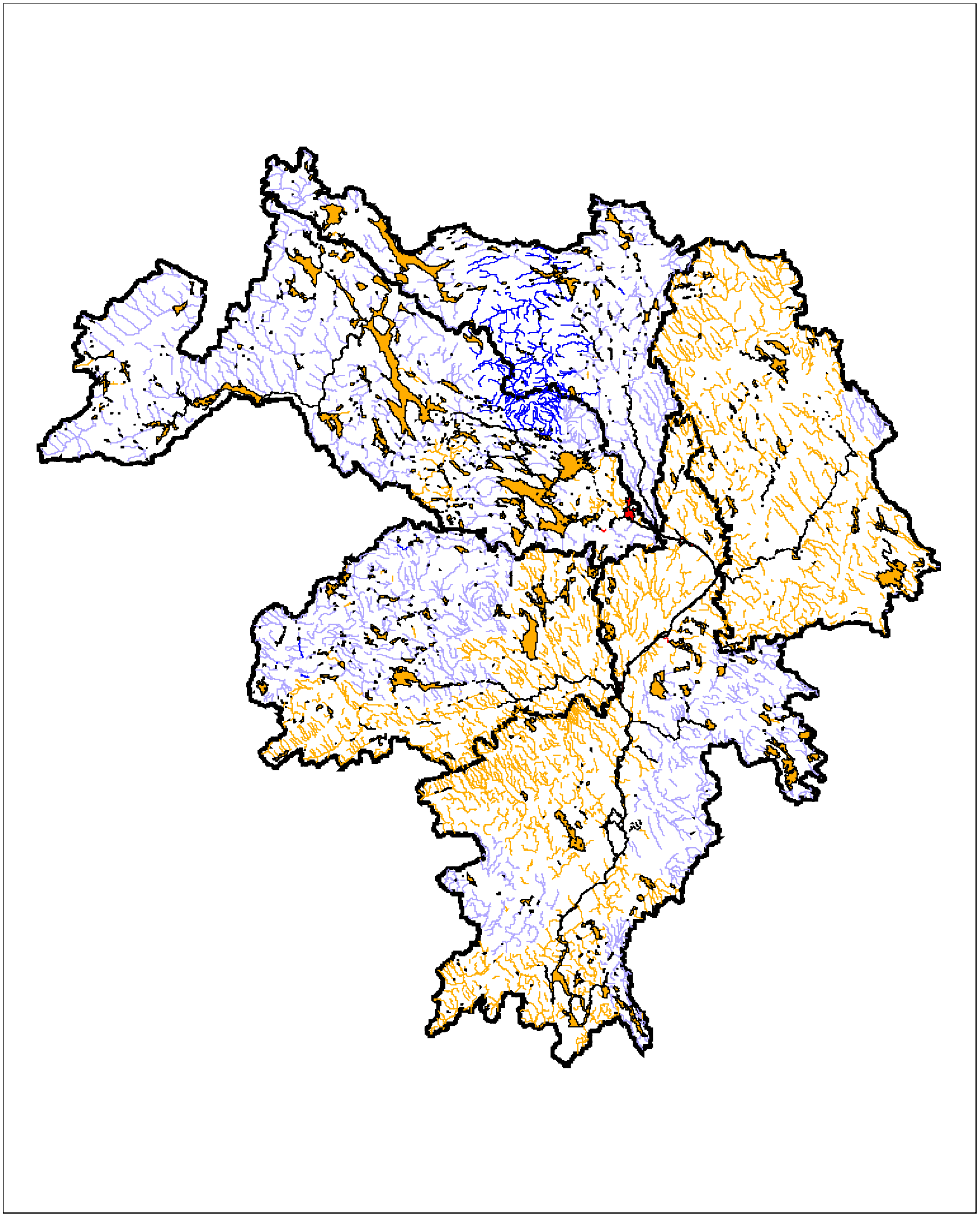


Figure 5. Location and type of point source discharges in the Penobscot basin. Combined sewer overflow=green circle; major discharge=red circle; minor discharge=gold circle; overboard discharge=purple square.

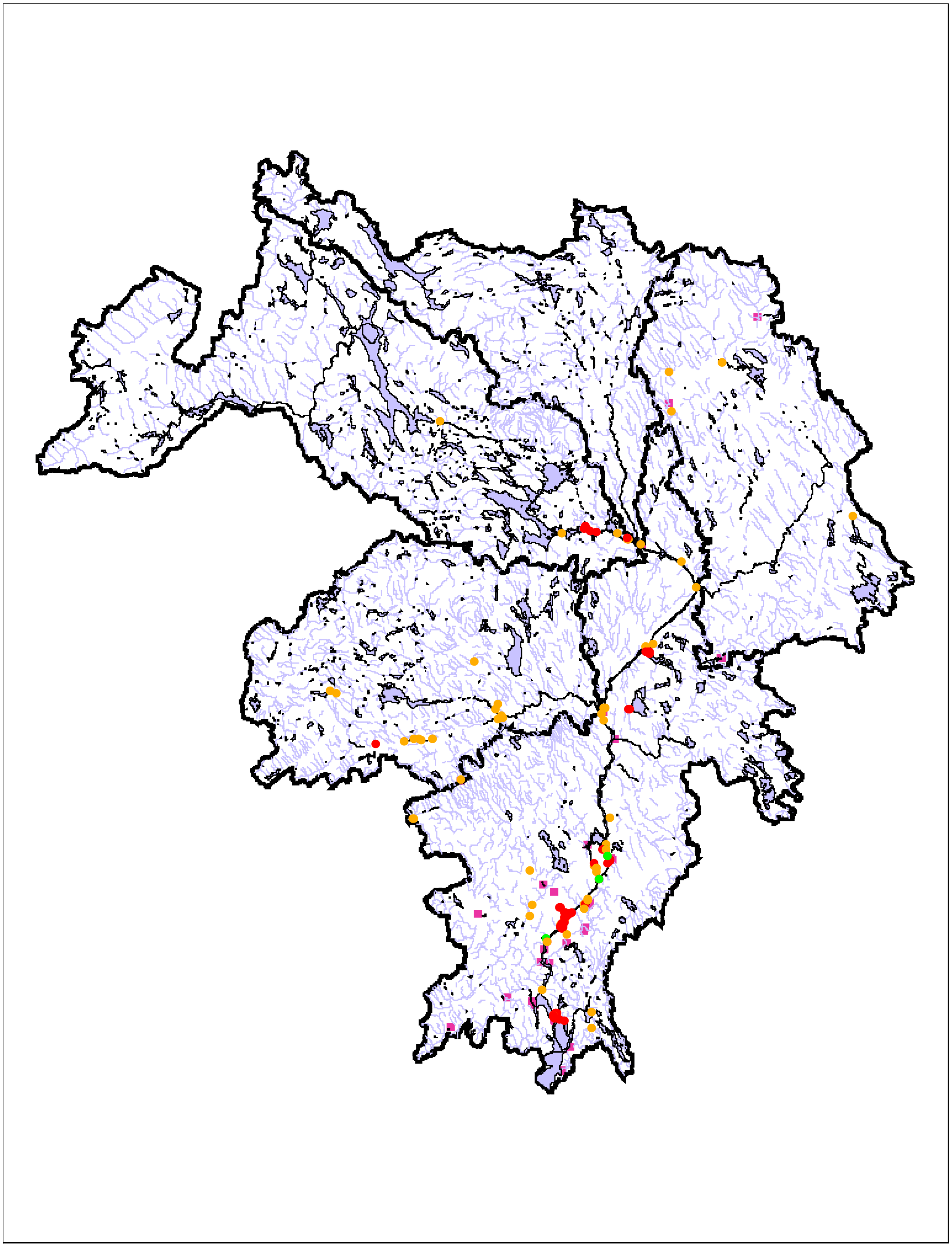


Figure 6. Location of fish health advisories.
Mercury advisory=gray; dioxin and PCBs advisory=red.

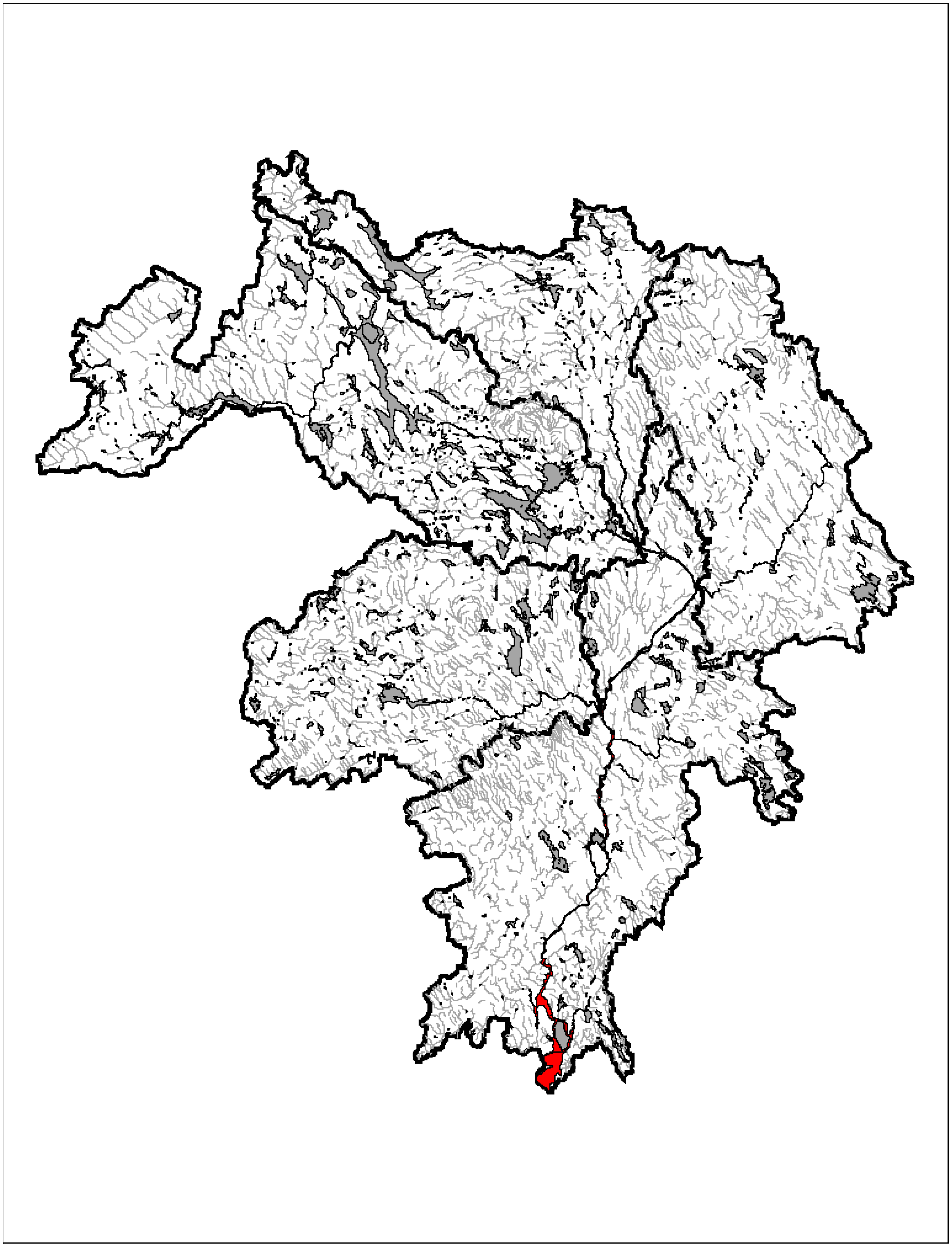


Figure 7. Number of Atlantic salmon returning to the Penobscot River and other rivers in New England from 1970 to 2006.

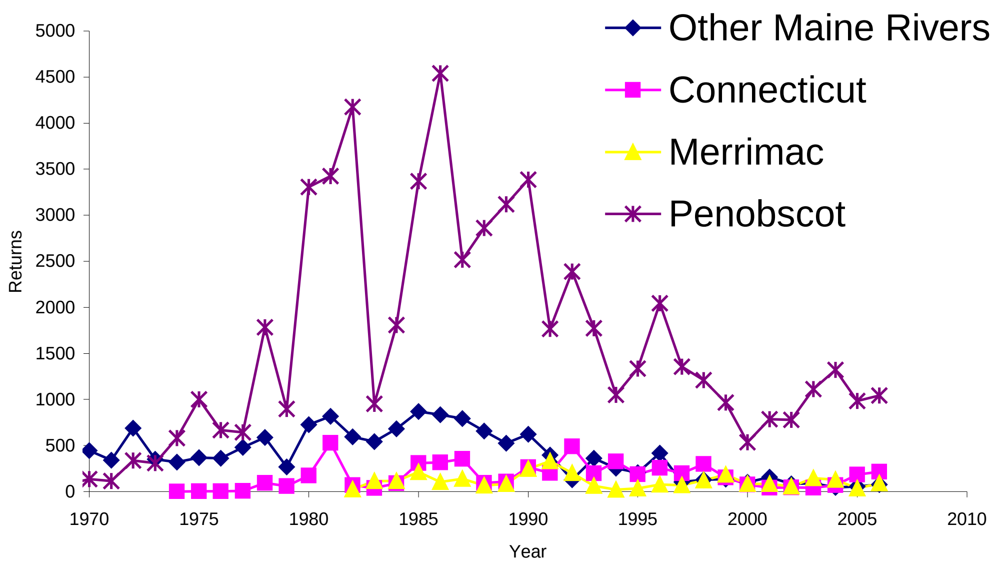


Figure 8. Number and origin (hatchery or wild/naturally reared) Atlantic salmon returning to the Penobscot River from 1970 to 2006.

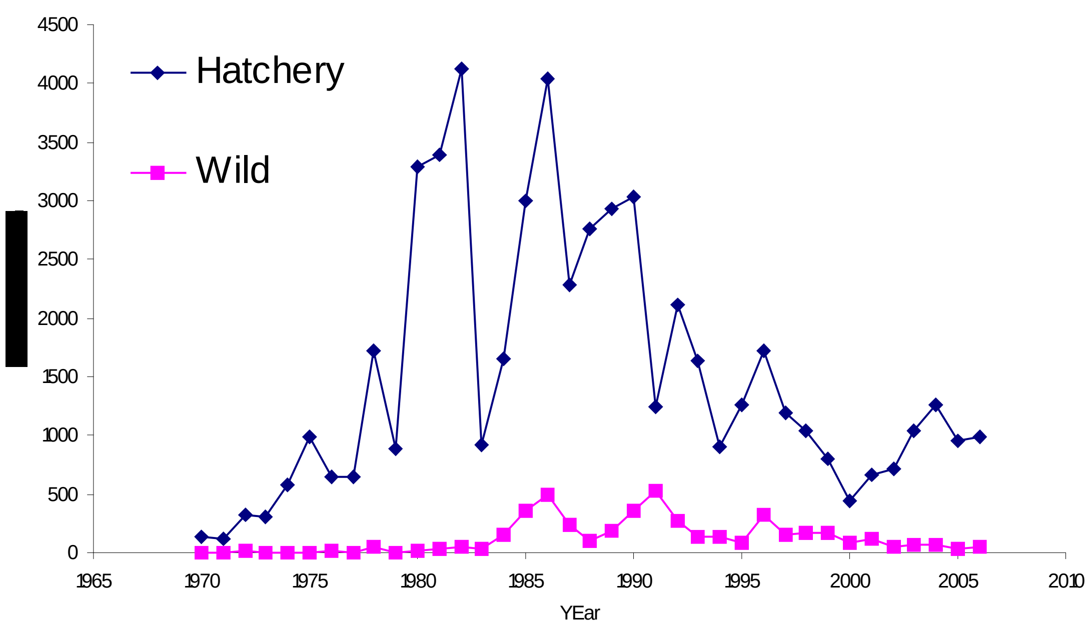


Figure 9. Return rate of 1SW and 2SW adults by cohort of hatchery-reared Atlantic salmon smolts released into the Penobscot River.

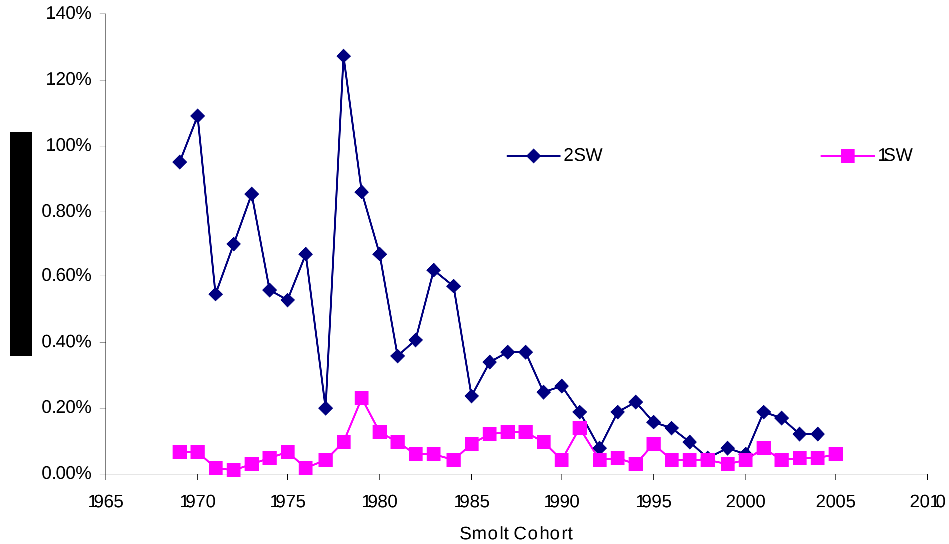


Figure 10. Number of juvenile Atlantic salmon stocked in the Penobscot River from 1970 to 2006.

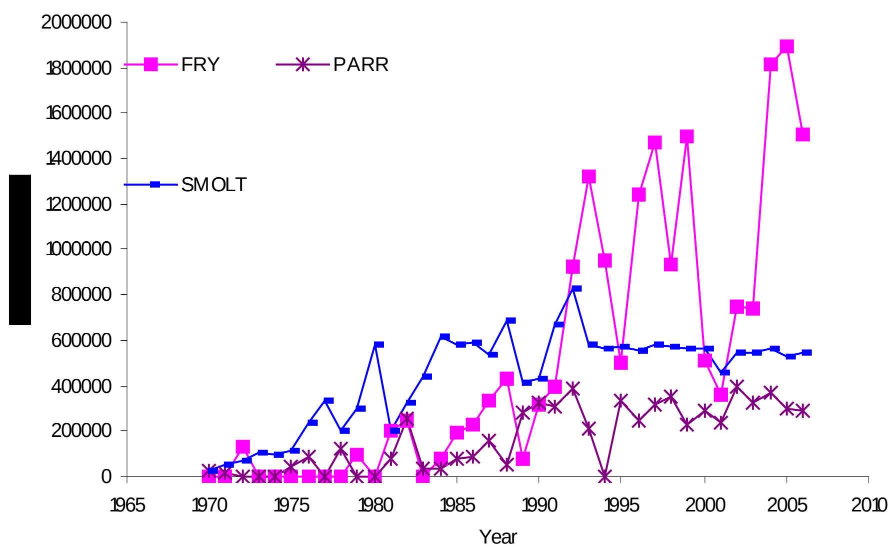


Figure 11. Historical habitat of American shad.

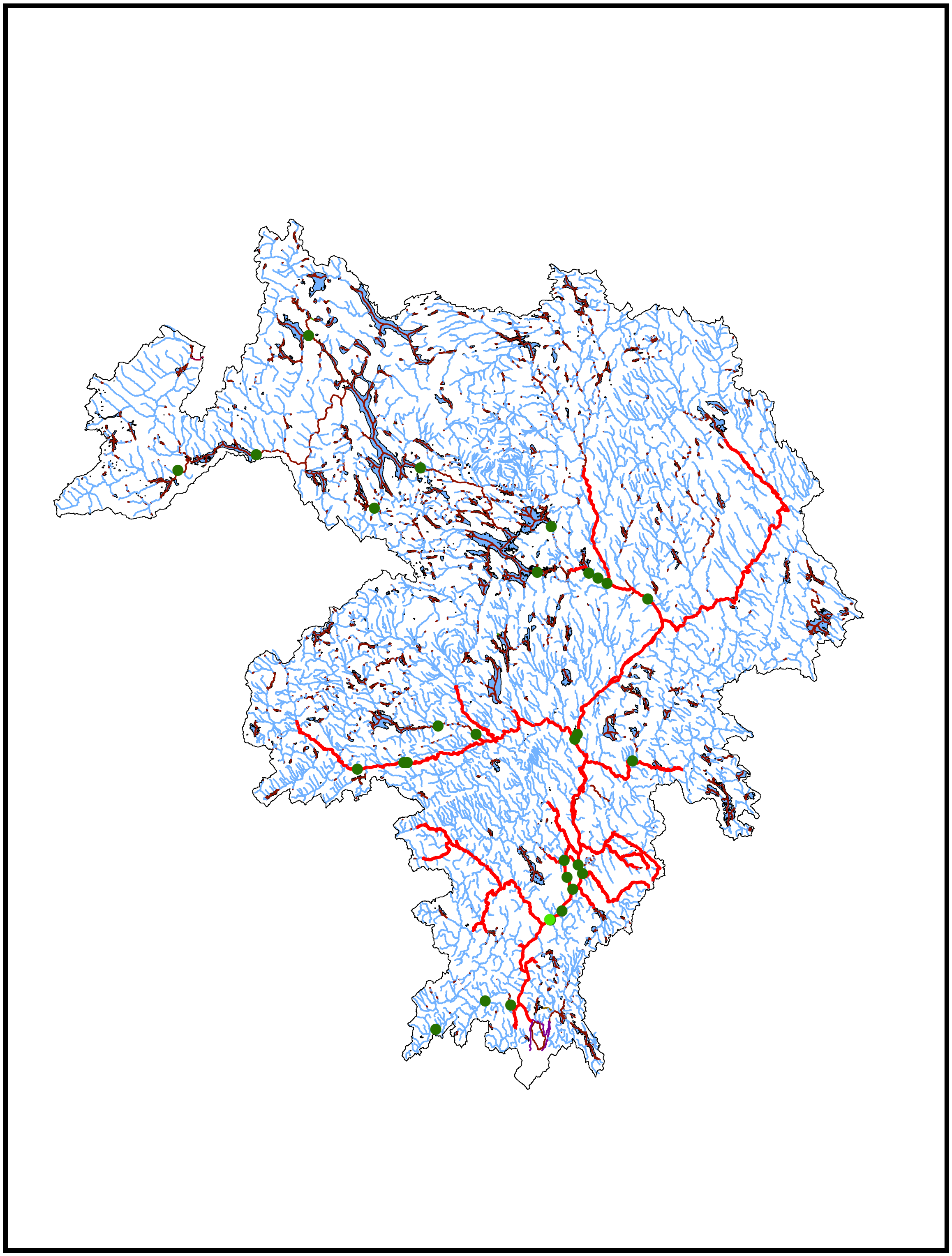


Figure 12. Accessibility of American shad spawning habitat before (top) and after (bottom) the Penobscot River Restoration Project.

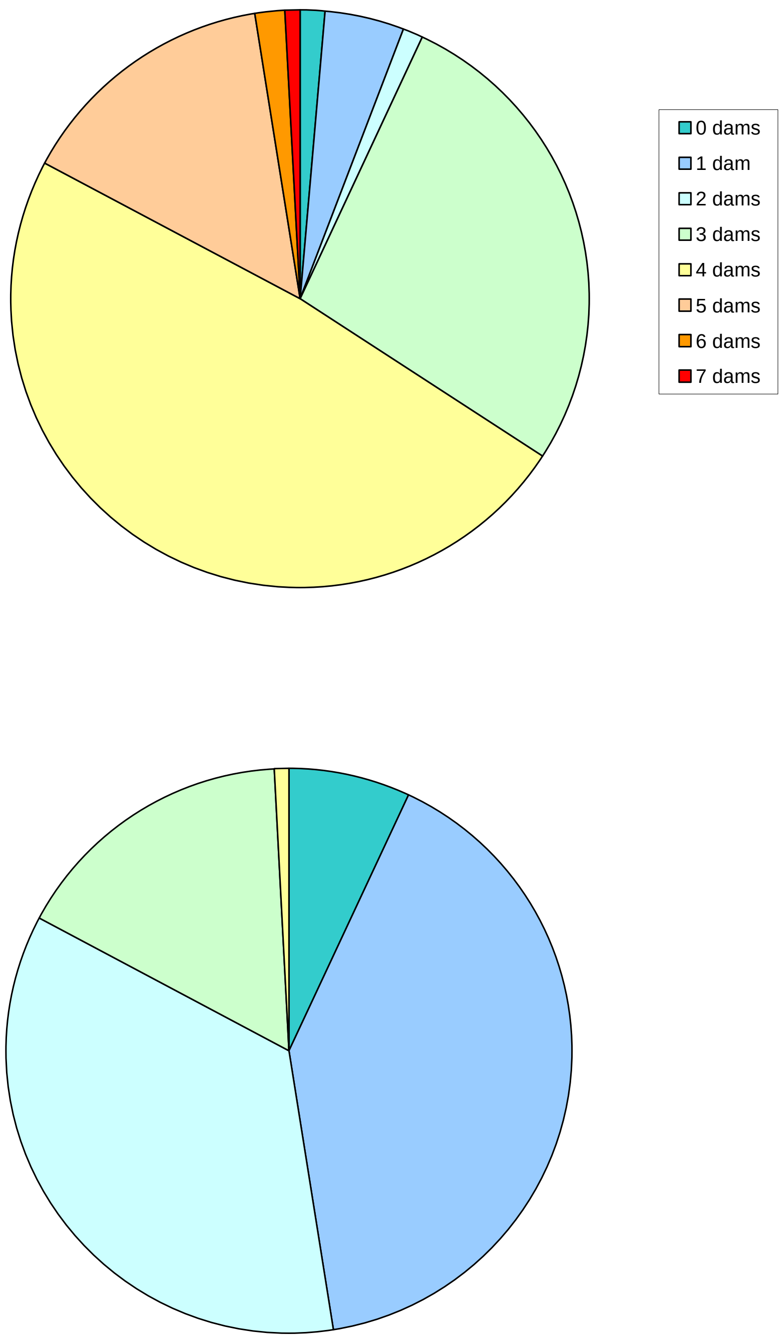


Figure 13. Historical migration routes and lake/pond spawning habitat of alewives in red; habitat in purple may not have been inaccessible.

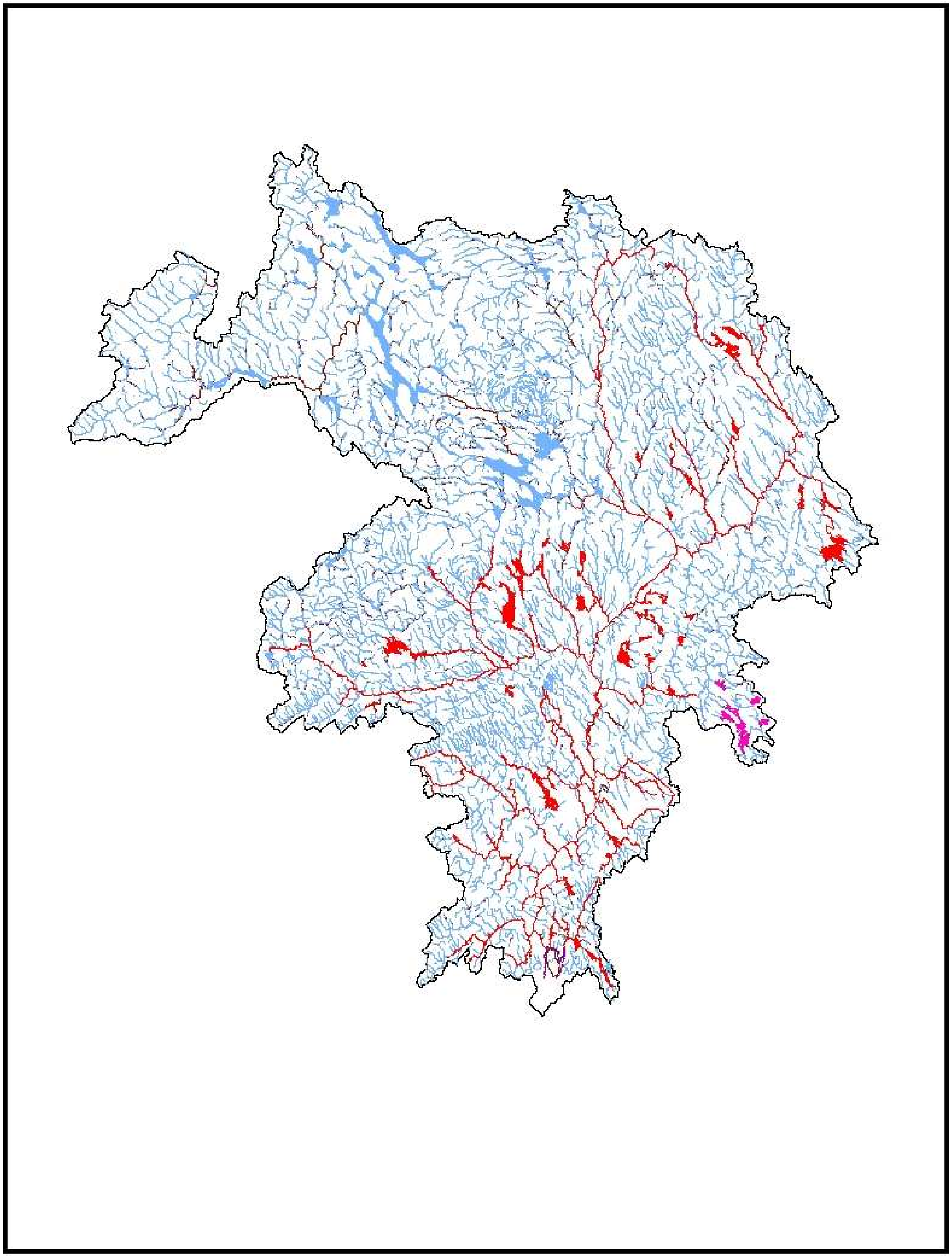


Figure 14. Accessibility of alewife spawning habitat before (top) and after (bottom) the Penobscot River Restoration Project.

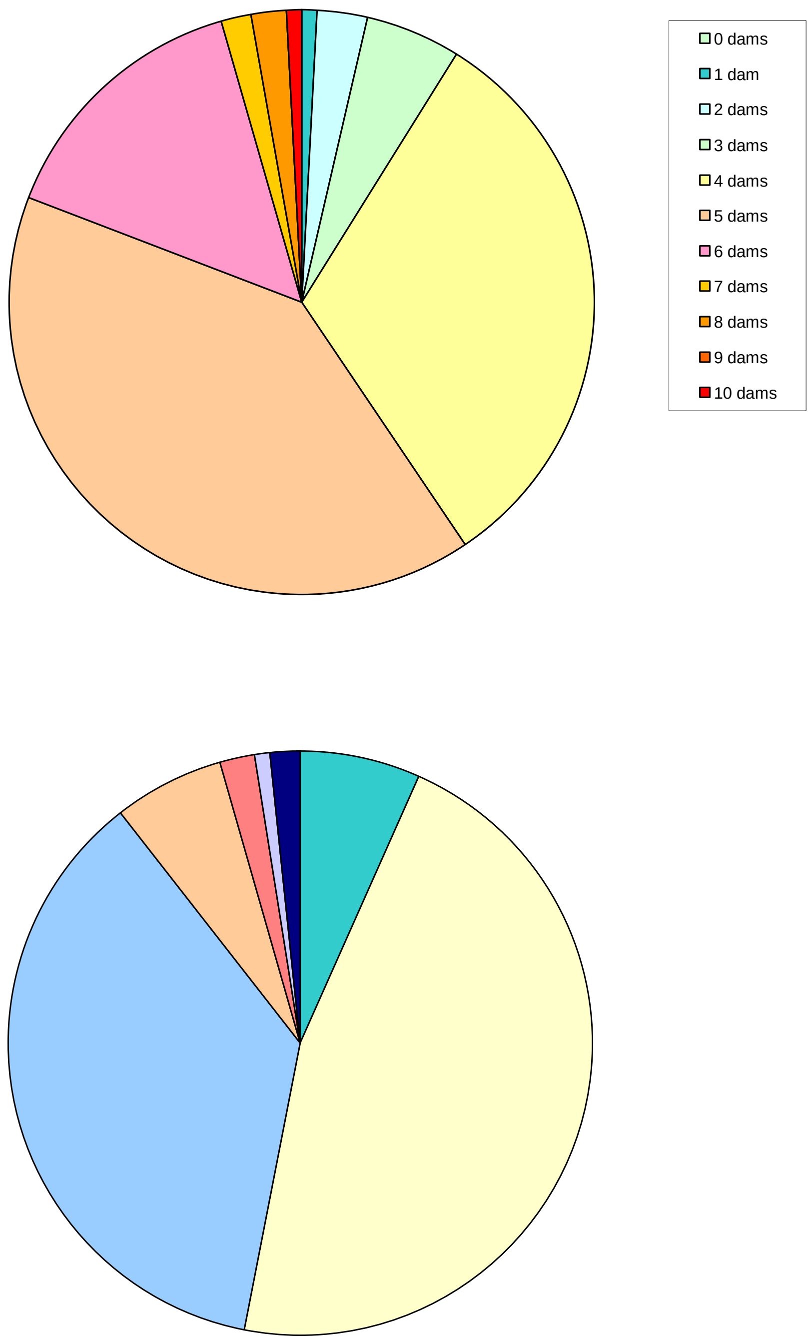
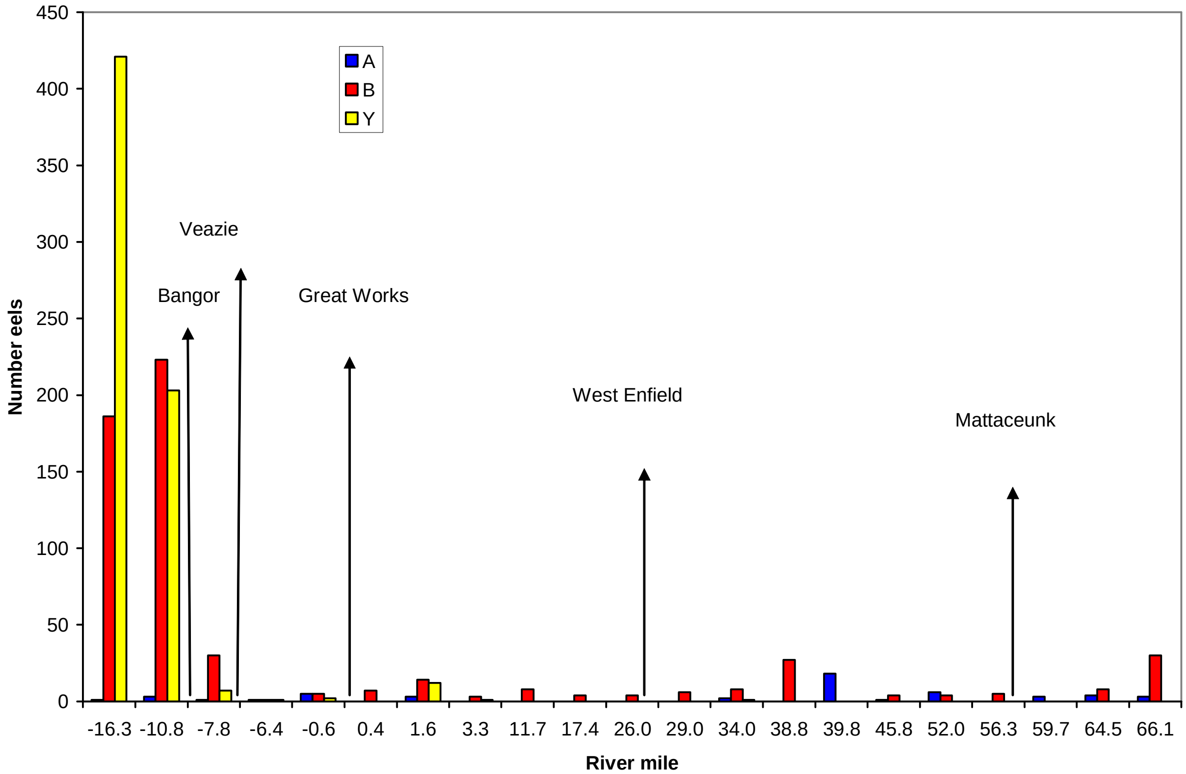


Figure 15. Number of American eel captured per km electrofishing (Data from Yoder et al. 2004).



Appendix A. A Historical Context for the Native and Commercial Fisheries of the Penobscot River.

Native Fisheries

For thousands of years, the migratory fish of the Penobscot River have been sought by Indians living along the river and its tributaries. Many Penobscot Indian place names refer to an abundance of migratory fish. Passagassawaukeag River and estuary in Belfast translates to sturgeon fishing or spearing place. The Penobscot word Mattamiscontis, which means a fishing place for alewives, is the name of a stream entering the west side of the Penobscot River above Howland. Blackman Stream in Bradley, which drains Chemo, Davis and Holbrook Ponds in Eddington, was also named Mattamiscontis by the Penobscot Indians in reference to the abundance of alewives there. Kenduskeag Stream in Bangor derives its name from an eel fishing place at the mouth of the stream.

Archaeological evidence shows native inhabitants on the Penobscot fished for American shad as early as 8,000 years ago and for sturgeon as early as 3,000 years ago. Shad bones found in native settlements along the Sebec River in Milo are dated to 6,000 to 8,000 B.P. Sites where sturgeon remains have been found include the junction of Pushaw and Dead Streams in Alton, the Penobscot River at Old Town and numerous sites in Penobscot Bay. In 1722, Colonel Thomas Westbrook noted the abundance of sturgeon, striped bass and eels near the Penobscot Indians' fort at Indian Island in Old Town. He stated:

"The Captives Inform'd me That the most part of the Indians food During the Time of the Seige was Seals which they Caught Dayly Keeping out a party of Men for that Purpose They Also Inform us & do Assert That there is great Quantity's of Sturgeon, Bass and Eels to be Caught Even Close by the Island where Penobscut Fort is."

The Atlantic sturgeon (*Acipenser oxyrhynchus*) has been prized by Indians in Maine and New England for thousands of years. Atlantic sturgeon reach enormous size, as long as eighteen feet and over 1,000 pounds. Archaeological evidence shows that Atlantic sturgeon have been hunted by Indians in numerous sites along Maine's coast and larger rivers for 6,000 years. Atlantic sturgeon were among the first river fish sought by early Europeans in Maine and New England in the 1600s.

In 1634, William Wood described the Indians' methods of hunting Atlantic sturgeon:

"They make very strong sturgeon nets with which they catch 12'-18' fish in day time. In nighttime they take to their birchen boats in which they carry a 40 fathom line with a sharp bearded dart fastened at one end. Then lighting a torch made of birch rinds, they weave it to and again by their boat sides which the sturgeon much delighted, come and tumble and play, turning up his white belly into which they thrust the lance, the back being impenetrable."

In his 1643 book, "Key to Language in America," Roger Williams of Rhode Island provided this entry:

"Kauposh/ Kauposhshauog -- Sturgeon

Diverse parts of this country abound with this fish; yet natives for their goodness and greatness of it, much prize it, and will neither furnish the English with so many, nor so cheap, that any great trade is to be made of it, until the English themselves are fit to follow the fishing. The natives venture one or two in a canoe, and with a harping iron, sticke this fish and haul it into the canoe, sometimes they take them by their nets, which they make of strong hemp."

As a boy, Capt. John Gyles was a war captive of Maine Indians and the French along the Penobscot and St. John Rivers 1689 to 1698. During his captivity, he accompanied an Indian who was sturgeon fishing, possibly in the lower Penobscot River. He wrote: "I was once fishing with an Indian for sturgeon, and the Indian darting one, his feet slipped, and he turned the canoe bottom upward with me under it ... So while he was taking care of his fine sturgeon, which was eight or ten feet in length, I was left to sink or swim."

John Josselyn was a settler of Black Point in Scarborough, Maine who travelled extensively along the Maine coast in the late 1600s. He provided a description of the fishery methods of Indians he met during his travels in Maine:

"The Alewives they take with Nets like a pursenet put upon a round hoop'd stick with a handle in fresh ponds where they come to spawn. The Bass and Blew-fish they take in harbours, and at the mouth of barr'd Rivers being in their Canows, striking them with a fisgig, a kind of dart or staff, to the lower end whereof they fasten a sharp jagged bone (since they make them of Iron) with a string fastened to it, as soon as the fish is struck they pull away the staff, leaving the bony head in the fishes body and fasten the other end of the string to the Canow: Thus they will hale after them to shore half a dozen or half a score great fishes: this way they take the Sturgeon; and in dark evenings when they are upon the fishing ground near a Bar of Sand (where the Sturgeon feeds upon small fishes (like Eals) that are called Lances sucking them out of the Sands where they lye hid, with their hollow Trunks, for other mouth they have none) the Indian lights a piece of dry Birch-Bark, which breaks out into flame & holds it over the side of his Canow, the Sturgeon seeing this glaring light mounts to the Surface of the water where he is slain and taken with a fisgig. Salmons and Lampres are catch'd at the falls of Rivers."

The alewife (*Alosa pseudoharengus*) was once ubiquitous to the coastal rivers and streams of Maine and New England. This migratory fish ascended the Penobscot by the millions until dam construction in the 18th and 19th centuries. Various sources state the name alewife is derived from the Native American word for the species. No eyewitness descriptions of the early Penobscot Indian fisheries for this species are known. A good description of the Native American alewife fishery in New England comes from southeastern Massachusetts. William Briggs, Jr., a settler in the mid-1600s, described the alewife fishery at Taunton, Mass. conducted by the Pokanocket band of Wampanoag Indians:

'The Indian name for Taunton is Cohannit, at first given to the falls in ye Mill River where the old Mill (so called) now stands, being the most convenient place for catching alewives of any in those parts. The ancient standers remember that hundreds of Indians would come from Mount Hope [Montaup] and other places every year in April, with great dancings and shoutings to catch fish at Cohannit and set up theyr tents about that place until the season for catching alewives was past and would load their backs with burdens of fish & load ye canoes to carry home for their supply for the rest of the year and a great part of the support of ye natives was from the alewives."

Wood and stone weirs along streams and ponds have been used for millenia to harvest migratory fish in the rivers of Maine and New England. The recent discovery of the remains of a large fish weir on Sebasticook Lake in Newport, Maine indicates this method was used by native people in central Maine as early as 5,700 B.P. Today, wooden fish weirs are still used in the

Penobscot River drainage to capture adult American eels as they migrate to the ocean to spawn.

Collapse of the Fisheries

Records indicate that during the late 18th and early 19th centuries, the Penobscot Nation repeatedly protested encroachment of their fishing and property rights along the Penobscot River.

During the Revolutionary War, Penobscot Chief Joseph Orono visited Boston and informed Massachusetts officials the tribe resented the recent construction of a sawmill and dam at the mouth of the Stillwater Branch of the Penobscot River. A transcript of the conference reads:

"Indians [presumably Chief Orono]: We don't want money for our lands, we don't sell our lands, we want to have those people removed, we don't want to have them live upon our lands.

"President: Did those that now live among you get the consent of your Chiefs?

"Indians: They never consulted them, there never was an Indian that gave Coburn liberty to erect the Mill he placed on their lands."

A bitter dispute began in 1804 and 1805 when Salem Towne, the Massachusetts agent for the sale of Indian Lands, sold three islands in the Penobscot River at Old Town to Joseph Treat and his associates. These islands were located at Old Town Falls and named in town plans Islands Four, Five and Six. Island Five was known as Shad Island, a key shad fishing and drying station for the Penobscots at Old Town Falls.

MacDougall (1987) states: "The Penobscots asked the Governor of Massachusetts through the medium of their agent, General Blake, to purchase Shad Island for them. On June 17, 1805 the land agent sold nine islands to Joseph Treat. The Penobscots complained bitterly about the sale of three of these, especially Shad Island, which was an important fishing station. In his report to the Governor and Council of Massachusetts, dated December 3, 1811, General Blake reported that the Indians felt themselves much injured by the sale of their island called Shad Island: 'This island is extremely well situated for shad fishing which fish the Indians depend upon a great measure for their subsistence.'"

A February 26, 1813 resolve of the Massachusetts Legislature paid Joseph Treat $100 in exchange for returning ownership of these three islands back to the Commonwealth of Massachusetts. The resolve also provided Treat with "a further sum of one hundred dollars, for damages done to the said Treat and his associates, by the Indians, in pulling down a fish store." This language of the resolve indicates that Treat used the islands for conducting a shad fishery at Old Town Falls.

Also in 1813, John Blake, the Massachusetts agent for the Penobscot Indians, stated in a letter the Penobscots demanded the removal of a sawmill and dam built on the Mattawamkeag River. Blake said:

"... upon a branch of the river called Mattawamkeag, being on the Indians land which mill is the cause of the destruction of much timber in the vicinity and the saw of which prevents fish from going into the ponds and lakes above."

Large scale commercial fishing in the lower Penobscot and the introduction of highly effective fish weirs in the Bucksport and Frankfort areas prompted the following 1821 petition by the chiefs of the Penobscot Indians to the Maine Legislature:

"To the Whole Legislature of the State of Maine

We the undersigned Chiefs & others of the Penobscot Tribe of Indians ask you to hear us in our petition in which we mean to speak nothing but truth and first we would say that in the days of our forefathers the great plenty of fish which yearly came into the waters of our Penobscot River was one of the greatest sources by which they obtained their living and has so continued within the remembrance of many of us who are now living which plenty we always considered as sent us by the Great God who provides means for all his Children --

But when our white brethren came amongst us they settled on our lands at and near the tide waters of our River and there was plenty of fish for us all -- but within a few years our brethren the white men who live near the tide waters of our River have every year built so many weares that they have caught and killed so many of the fish that there is hardly any comes up the River where we live so that we cannot catch enough for the use of our families even in the season of the year when Fish used to be most plenty.

We have asked the general Court at Boston to make laws to stop the white people from building weares and they have made Laws but they have done us no good for the Fish grow more scarce every year. Besides the weares they use a great many long nets. We can only use very small nets and spears -- now we ask you to make a Law to stop the white folks from building any more weares forever so that Fish may again become plenty and also stop the white people from using any seines above Kenduskeag on the main river.

And we ask you to make the Law so as to stop the white people and Indians from catching fish more than two days in the week in the season of Salmon, Shad and Alewives at least for five years. We think that Fish will then be plenty again.

We are your Brothers.

John Neptune (his mark)
Lorey (his mark)
Peal Moley (his mark)
Peal Tomer (his mark)
Joseph (his mark)
Solomon (his mark)"

This petition sparked a counter petition signed by 175 commercial fishermen opposed to the changes in the fish laws recommended by the tribe. An excerpt of petition reads:

"Our "red brethren" have been instigated by some of their white brethren, far up the river, to make a talk about the destruction of salmon, by our expert fishermen on the big waters -- It will be found on investigation, that they have contributed their full share, to the destruction of the fish, not for their own use or consumption, but for fish merchants. When a salmon has run the gauntlet and arrived unharmed at the still waters, where the spawn is deposited, it becomes an object of solicitude; for by spearing them in these retired places, as has been the constant practice of the Indians, the destruction of a single fish is that of thousands. Here it is then, if any where, that arbitrary and insolent fishwards should be appointed to execute the vengeance of the laws. The Indians are now reduced to mere handful of strollers, having no regular residence and have really little or no interest in the result. All of which is submitted for your consideration, with that deference, which is always due from the people, to the impartial and upright Legislature of their choice."

MacDougall (1987) states that in 1830, the tribe asked the Maine Legislature to restore their fishing rights to the Old Town Falls and Shad Island. This request was made again in an 1831 letter by John Neptune and Joseph Socbasin to Maine's governor. The Penobscots also reported white settlers would not let them land their canoes on several islands near Naskeag Point in eastern Penobscot Bay to conduct fishing operations there. MacDougall (1987) states that treaties between the Penobscot Nation and Massachusetts reserved the Penobscots' right to use several islands near Naskeag Point in Brooklin for fishing operations.

Atkins and Foster (1869) state that construction of large dams on the river at Veazie, Great Works Falls and Old Town Falls in the mid 1830s decimated the river's shad and alewife populations. None of these dams had fishways, even though they were required by state law. Atkins and Foster reported that some of the strongest salmon were able to leap over these dams and migrate upriver past Old Town.

This situation is supported by correspondence from Penobscot Indians to the Maine Legislature in the early 1840s. At this time, the Penobscots' fishery privilege at the top of Old Town Falls was leased to an Indian, Joe Mary Mitchell and an English settler, Isaac Winslow, who constructed a stone fish weir at the top of the falls to stop fish so they could be caught. In 1843, documents report that the pair took between 150 and 300 Atlantic salmon at the falls, and paid the Penobscot Nation $15 for the lease of the fishing privilege for the year. Despite extensive correspondence about this small fishing operation in Legislative documents, no mention is made of any harvest of shad or alewives at this fish "dam" at the falls -- only Atlantic salmon.

Documents regarding the Penobscot Indian fisheries during the latter part of the 19th century are scarce. Dams constructed at Veazie and Great Works ended traditional fisheries for sturgeon or striped in the vicinity of Old Town. By the Civil War, alewife and shad populations were severely depleted due to inadequate fish passage at dams, and few were successful in migrating up the river to Old Town. This left Atlantic salmon and American eel as the only remaining migratory fishery resources available to tribal members at and above Old Town.

In his 1940 book Penobscot Man, Dr. Frank Speck provides a history and description of various fishing methods used by the tribe, gained from interviews with Penobscot tribal members at Old Town in the early 20th century. Speck provides two detailed descriptions of late 19th century tribal fisheries for adult American eel fisheries using weirs on the Passadumkeag River and by stunning eels in Sunkhaze Stream with an extract of the pokeberry plant introduced into the water.

By the time of Speck's research, tribal fisheries at Old Town for all migratory fish except American eel had ended. He states:

"To these Indians, practically all of whom lived near the Penobscot River, the spearing of salmon in their annual run up-stream in June, July and August was one of the great seasonal events. When the lightning bugs begin to appear late in June, they say it is a sign for salmon spearing. The Penobscot salmon sometimes attain a weight of forty pounds. During the run, just above the falls or rapids, the men would occupy some ledge and spear the fish as they came by. Camps were established in such vicinities. At other times they went in canoes, the bow man with a spear watching for fish. At night a torch consisting of a green stave, split at the end to hold a bundle of folded birch bark strips wound with splints and frayed at the ends was fastened to the bow of the canoe. These methods of catching salmon were practiced until 1912, when spearing was prohibited by the makers of the game laws."

The impact of dams on the river on tribal fisheries was emphasized by Speck:

"Just below Indian Island, above the falls, there is in the middle of the river a rocky ledge where the men used to get their stock of salmon. Unheard-of quantities were taken here by the tribe until the dam was built. In those days they feasted on the fresh fish and smoked a large amount of it for winter upon pole racks over a fire."

The complete absence of reference to shad and alewife fisheries at Indian Island in Speck's work conforms with other records showing shad and alewife migrations to Old Town had ended long before the time of his research. The last known record of tribal fisheries for shad and alewives at Old Town dates to the 1820s era, before the construction of dams at Veazie and Great Works.

Commercial Fisheries

I. Pre-Dam Fisheries (1780-1835)

Commercial harvest of the Penobscot River's migratory fish species began soon after the settlement of Bangor and Bucksport in the1760s. From the late 1700s to 1830s, fishing was conducted primarily with seines, drift nets and brush weirs in the tidal portion of the river from Bangor to Bucksport. Fishtraps, nets and spears were used at the river's various rapids from Old Town to Bangor. As the 19th century progressed, weirs became the dominant fishing method, with most located in the river's estuary and Penobscot Bay. Species targeted included Atlantic salmon, striped bass, American shad, alewives, smelt and tomcod. It is uncertain if sturgeon were commercially targeted, although one report states that large sturgeon were often caught in drift nets and seines set for other species.

Several eyewitness accounts provide information on the early Bangor and Bucksport fisheries. One is from Capt. Jacob Holyoke of Brewer (born 1785), who fished with his father in Bangor in the late 1700s:

"Salmon, shad and alewives were very plenty, and in their season many people came here to catch them -- bass were also plenty, and in the fishing season, we could fill a batteau with fish at Treat's falls in a short time; we would sometimes take forty salmon in a day, and I think as many as five hundred were taken some days, in all. My father had a large seine in the eddy, just above the Bangor bridge, and we had much trouble with the sturgeon. When a large sturgeon was captured, the boys used to tie the painter of the boat to his tail and giving him eight or ten feet length of rope, let him go, and when he grew tired or lazy would poke him up with long sticks and so be carried all around the harbor."

Rufus Buck (born 1797), a descendant of the founder of Bucksport, provided this account of the early fishing activity in that section of the river:

"The principal business of the first settlers of this town was fishing and little attention paid to farming ... The Penobscot abounded with salmon, shad and striped bass and all the small streams with alewives. They were first taken by spearing and by nets and then by what was called half tide weirs. These were laid from point to point across deep coves and great numbers of shad and bass were taken in them. The bass were salted and dry cured and sent to Boston for market. In 1811 one Harnley Emerson came here from Phippsburg and built the first three pound weir at the mouth of Marsh River on Treat's Flats ... From this time the fishing interest became one of the most important sources of income to the town, amounting at one time (in the year 1820), to $30,000."

Records suggest that most of Penobscot's early commercial fish harvest was shipped to Boston and other ports to the south. Joseph Carr, who worked at his father's store at Carr's Wharf in Bangor, provided this eyewitness account from the early 19th century:

"All sorts of goods were kept for sale, and Saturday was the great day of trade, and Saturday afternoon (my just holiday) was usually spent by me on compulsion in waiting on my father's customers. On this day there came to the store men from the celebrated families of Harthorns, McPhetres, Spencers and Inmans, bringing with them shingles, salmon, shad, smoked alewives and credit, for which they wanted tea, tobacco, calico and rum ... I have often seen nets drawn full of shad and alewives in Kenduskeag Stream, both above and below the bridge, and before any wharves were built into the stream."

Soon after commercial fishing on the Penobscot River began, concerns were raised regarding overfishing. A 1791 petition to the Massachusetts General Court, signed by 117 local residents, claimed netting operations were excessive and causing great damage to the salmon and shad populations. The petition provides insight to the methods of the commercial fisheries at this time:

"Now the common custom and practice of many people on said River is to fish every day in the Week, to fasten several long nets together, from two, to Nine and so taking advantage of the Tide and slack water, Run them off the mainland and both sides of the Island, and in Narrow places of said River, in that position that said Nets do almost Intersect one another -- Others do ply their long Nets off and on as the tide Ebbs and flows -- By which reason the course of the salmon is stopped, the shoals broken, the fish scattered and so affrighted; that there is the greatest danger of their course being intirely turn'd and all the fishery Ruin'd (If not timely prevented)."

Beginning in 1786 and continuing for many decades, the Massachusetts and Maine Legislatures enacted numerous laws attempting to regulate the Penobscot fisheries. Laws were passed to limit the length and depth of nets; outlawing the joining of large nets; restricting the duration of the fishery; requiring weirs to be left open one or two days per week during the fishing season; and requiring fish passage at mill dams on the river and its tributaries. Enforcement of these laws was left in the hands of fish wardens appointed by the towns. Records suggest these fish wardens were too few in number or reluctant to prosecute violators.

The 1791 petition states: "And they that are Chosen and duly Engaged to Inspect the fishery do Exercise no authority to prevent the same, But some do even fish themselves, or tolerate others, etc."

In the late 1860s, the Maine Commissioners of Fisheries conducted interviews with older commercial fishermen of the Penobscot to develop a history of the early fisheries. Their 1869 report provides this overview:

"In old times the most abundant fish (in bulk) in this river was the shad; this was probably the most valuable. Next came the salmon. Alewives were exceedingly abundant but little esteemed. Bass (Roccus lineatus, Gill.) were not rare. At Oldtown falls as many shad and alewives were taken as would supply the demand, and many fold more might have been taken; the price, one dollar per hundred for shad, was not sufficient inducement to provide beforehand the necessary barrels and salt to take care of them.

"On the lower part of the river the market was more convenient, many vessels, mostly from Connecticut, coming every season to load with shad and salmon. Immense quantities of them were shipped in this way. Before the river was closed with the dams the price of salmon had risen to six cents a pound, that of shad to six cents apiece. Alewives, smoked hard for the West India market, brought in early times thirty-three cents a hundred in Boston, and the price afterwards rose to one dollar and one dollar and quarter, when they were very profitable. The fishing, previous to 1785, was all done with nets, but they have been gradually superseded by weirs and at the present time very few nets are used. Their use, however, was continued as long as it was profitable. At one time there were, it is estimated, two hundred men employed in drifting between Mill Creek [South Orrington] and Olamon's [Odom's] Ledge."

After four decades of commercial fishing, the Penobscot still produced large harvests of salmon, shad and alewives. This was illustrated by an item in the May 26, 1829 edition of the Kennebec Journal, which read: "A true fish story -- Seven thousand shad and nearly a hundred barrels of alewives were taken in Eddington last week by Luther Eaton, Esq. at one haul -- Bangor Register."

II. Post-Dam Fisheries (1830-1900)

The Penobscot commercial fishery was radically altered in 1834 with the construction of a large dam at Eddington Bend near the site of the contemporary Veazie dam. Dams at Great Works and Old Town, built several years prior, only partially spanned the river. The Veazie dam was the first to completely block the river. Despite state fish passage laws and the dam company's Legislature charter, which required the provision of fish passage, no fishway was built at the dam.

In their 1869 report, the Maine Fisheries Commissioners described the impact of these new main-stem dams:

"[The river] was then nearly closed by Fiske and Bridge's dam at Oldtown Falls, in which there was and still is a passage by which some salmon pass every year; and in favorable seasons shad and alewives pass in limited numbers. After this the Great Works dam was built, and in 1834 or 1835 the Veazie Dam. The latter was closed in the winter. When the fish came in the spring they found an impassable barrier across their way; they gathered in multitudes below the dam and strove in vain to surmount it; many returned down the river, and after the usual time for spawning of shad was past they were taken in weirs in the town of Bucksport, loaded with ripe spawn they could no longer contain; a phenomenon which Mr. John C. Homer who has fished with weirs at that point for forty-three years had never observed at any other time. These were doubtless shad whose natural spawning grounds lay far up the river, and who had after long contention given up the attempt to pass the Veazie Dam. A great many shad and alewives lingered about the dam and died there, until the air was loaded with the stench."

By the 1830s, most of the river's tributaries below Old Town were blocked by dams with no fishways. Also blocked was the Stillwater Branch of the Penobscot River in Orono, the migration route for alewives to Big and Little Pushaw Ponds. In 1838, the Maine Legislature exempted dams on Blackman Stream, Kenduskeag Stream, Cold Stream, the Piscataquis River at and above Dover, Sebec Stream and Sedgeunkedunk Stream from providing any fish passage.

Dam construction on the lower Penobscot in the 1830s greatly impacted the rivers' striped bass and sturgeon. The Veazie Dam prevented these fish from reaching all of their spawning habitat above the river's head of tide. American shad were greatly impacted due to their inability to leap over lower river dams. The increasing number of mill dams and logging dams on lake and pond outlets prevented alewives from reaching most of their native habitat in the Penobscot River. Due to their leaping ability, some Atlantic salmon were able to leap over the lower dams and reach the river's upper tributaries.

The decline in fisheries after dam construction in the 1830s caused the collapse of the drift net fishery from Brewer to Bucksport. The value of net fishing privileges along the Penobscot by the towns of Brewer and Orrington also collapsed during this period. In 1869, the Maine Fisheries Commissioners reported:

"The fishing is at the present day is almost entirely confined to weirs. Set nets do not pay, nor do drift nets except near the falls. Mr. Simeon B. Rich, of Bucksport, fished with a drift net thirty and forty years ago and would sometimes get three hundred shad in a single night; in 1867 he tried it again, but caught no more than three shad in any one night -- sometimes two, one or none."

The 1869 Fisheries Commissioners report describes the challenges the Penobscot's fish faced in attempting reach spawning grounds during the Civil War period:

"For a few years after the construction of these dams, fish were abundant; then a rapid decline set in, and in a few years they were comparatively scarce. In the case of salmon, they reached their lowest point ten years ago, since which time there has been a considerable increase, which may be owing to some increased facilities for passing the dams. We know that the water has made a way for itself around the end of Veazie Dam, where enough water flows to enable salmon to surmount it, so that at the present time, as stated in our last report, salmon, the most rigorous ones, that come at the right season, and do not get caught in the traps set on the falls, can reach the head waters of some of the upper branches. But the decrease of shad has never ceased. They are growing constantly less, and instead of exporting shad by the cargo, the people of the Penobscot valley are forced to import from other rivers shad for their own consumption."

III. First Restoration Effort (1870-1900)

In response to the sharp decline of migratory fish populations across the state, the Maine Legislature created the Maine Fisheries Commission in 1868 and charged it with rebuilding the state's migratory fish stocks. The first commissioners, Charles Atkins and Nathan Foster, conducted extensive surveys of each river, interviewed hundreds of commercial fisherman, and inspected most major dams. They identified the primary obstacles to restoration as impassable dams, over-fishing and pollution of the waters.

In 1869, the Commissioners stated that illegal fishing on the Penobscot was rampant:

"With regards to the laws regulating the fishery, they do not appear to be regarded on this river [Penobscot]. The act of the last Legislature prohibiting the fishing within a half mile of the lower falls has been openly and continuously violated, and we are informed that the Bangor market has been principally supplied, and some shipped to Boston from drift nets on this forbidden ground. A trap has been set at the falls and taken many salmon. Evidently there is fault somewhere."

This period also marked the peak of the sawlog industry on the Penobscot. In 1872, more than 246 million board feet of logs were transported down the river and cut at sawmills located on the Penobscot and its tributaries. The in-river accumulation of sawdust, bark and wood scraps was cited by the Commissioners as destroying salmon and shad habitat throughout the Penobscot drainage.

Prior to the Civil War, an additional dam was constructed on the Penobscot's main-stem at Basin Mills Rips in Orono. In 1880, a new dam was constructed below the river's head of time at Bangor. This resulted in a total of five main-stem dams on the first 12 miles of the Penobscot above its head of tide. However, the fisheries commissioners convinced the owner of the Bangor Dam, the Bangor Waterworks, to include a fishway during its construction. This represents the first recorded instance where a dam owner on the Penobscot constructed a fishway at its dam.

In 1880, fishways were reported to completed at Basin Mills Dam and Great Works dams. Some passage was available at Veazie Dam due to a natural opening at the east end of dam. Some passage was available at Old Town due to the dams not traversing the entire river. Fishways were reported to be completed at three recently built dams on the Mattawamkeag River.

In 1880, the Penobscot Indian Nation informed the Maine Legislature: "We ask your aid in protecting for us our fisheries at Old Town which have been materially injured by the white man's building of dams and mills on the privileges adjoining our islands and thereby not only occupying our water privileges but destroying our fisheries."

Records indicate the ability of Penobscot salmon to reach headwater habitat during this period varied from year to year. In 1880, Forest and Stream magazine reported that H.L. Leavitt and J.F. Leonard caught an Atlantic salmon with a fly rod in Wassataquoik Stream, a tributary of the East Branch Penobscot that drains the flank of Mount Katahdin. In 1890, Charles Atkins erected a weir on the East Branch Penobscot to capture adult Atlantic salmon and reported, "on account of lower water they failed to surmount the dams on the lower Penobscot."

No information is available on the presence of shad, alewives or other migratory fish species above the Penobscot dams at this time.

After the Civil War, commercial Atlantic salmon landings on the Penobscot continued to decline from pre-dam conditions. In 1867, landings for 183 weirs and nets totaled 7,320 salmon. In 1880, landings totaled 10,000 salmon at 266 weirs and nets. In the 1890s, commercial salmon fishing effort declined 20 percent from the 1880s period and landings declined by 50 percent. Harvests in this period 4,400 to 6,400 salmon per year.

After 1880, recreational angling for Penobscot salmon became increasingly popular. Recreational catch records at the Bangor Salmon Pool ranged from 21 to 125 adult salmon per year from 1885 to 1900. These were the salmon that had survived the gauntlet of weirs and nets in the lower river. While not large in number, all recreationally caught salmon were killed, and only a portion of the total recreational catch was recorded.

IV. Industrial Pollution (1900-1970)

The health of the Penobscot River's migratory fish species has long been closely tied to the region's timber economy. The enormous quantities of virgin timber in the Penobscot River headwaters in the 1830s provided the investment capital to pay for large main-stem dams constructed during this period. These dams provided the mechanical power to cut and process billions of board feet of saw logs during the 19th century. By the 1840s all of the forests within 50 miles of Bangor were cut over. By the 1880s even the most remote parts of the Penobscot watershed had been heavily cut.

In 1900, the Penobscot River's timber economy shifted to pulp and paper production which could utilize trees of much smaller diameter than the saw log industry. Construction of pulp and paper mills along the river began in the early 1900s in Millinocket, Old Town, Brewer, and Lincoln. Numerous textile and shoe factories along the river were also built during this period. Because these industries required chemical processes, pollution of the Penobscot River with industrial waste increased dramatically. Untreated municipal waste from towns and cities along the river and its tributaries increased as well.

With the onset of industrial and municipal pollution, efforts at restoring the fisheries of the Penobscot faltered. New fishways were constructed at the river's lower dams in the 1930s, but nothing was done to stop the increasing water pollution. Nothing was done to provide passage at the many dams that blocked the Penobscot River's tributaries. During the 1920s and 1930s, the cities of Old Town and Bangor stopped using the Penobscot River as their public water supply because it was too polluted. In 1935 the Maine Fisheries Commissioners stated:

"The Penobscot shad catch in 1902 was 731,000 pounds and in 1935 it was much less than 100,000 pounds. This species is rapidly growing extinct. Our salmon are thinning out and are now only available in few streams. The smelts are growing scarce."

Appendix B. Agency Missions and Goals

Maine Department of Marine Resources: The Department of Marine Resources was established to conserve and develop marine and estuarine resources; to conduct and sponsor scientific research; to promote and develop the Maine coastal fishing industries; to advise and cooperate with local, state and federal officials concerning activities in coastal waters; and to implement, administer and enforce the laws and regulations necessary for these enumerated purposes, as well as the exercise of all authority conferred by this Part. The Department's goal for the Penobscot River is to restore, protect, enhance and manage self-sustaining[4] populations of native diadromous alewife, American shad, American eel, Atlantic salmon, Atlantic sturgeon, Atlantic tomcod, blueback herring, rainbow smelt, sea lamprey, shortnose sturgeon, and striped bass within their historical habitat in the Penobscot River basin for broad-based public use and benefit.

Maine Atlantic Salmon Commission: The Maine Atlantic Salmon Commission is the lead policy body for Atlantic salmon statewide.

Maine Department of Inland Fisheries and Wildlife: The Department of Inland Fisheries and Wildlife was established to ensure that all species of wildlife and aquatic resources in the State of Maine are maintained and perpetuated for their intrinsic and ecological values, for their economic contribution, and for their recreational, scientific, and educational use by the people of the State. In addition, the Department is responsible for establishing and enforcing rules and regulations governing fishing, hunting, and trapping, propagation and stocking of fish, acquisition of wildlife management areas, the registration of snowmobiles, watercraft, and all terrain vehicles, safety programs for hunters, snowmobiles, and watercraft, and the issuing of licenses (hunting, fishing, trapping, guide, etc.) and permits. In the Penobscot River drainage, the Department manages for both warm water and coldwater species.

[4] Self-sustaining populations spawn in the wild, and migrate to and from the ocean with a minimum of human interference.

Appendix C. Standards for classification of fresh surface waters [5]

The department shall have 4 standards for the classification of fresh surface waters that are not classified as great ponds.

1. Class AA waters. Class AA shall be the highest classification and shall be applied to waters which are outstanding natural resources and which should be preserved because of their ecological, social, scenic or recreational importance.

A. Class AA waters shall be of such quality that they are suitable for the designated uses of drinking water after disinfection, fishing, recreation in and on the water and navigation and as habitat for fish and other aquatic life. The habitat shall be characterized as free flowing and natural.

B. The aquatic life, dissolved oxygen and bacteria content of Class AA waters shall be as naturally occurs.

C. Except as provided in this paragraph, there may be no direct discharge of pollutants to Class AA waters.

(1) Storm water discharges that are in compliance with state and local requirements are allowed.

(2) A discharge to Class AA waters that are or once were populated by a distinct population segment of Atlantic salmon as determined pursuant to the United States Endangered Species Act of 1973, Public Law 93-205, as amended, is allowed if, in addition to satisfying all the requirements of this article, the applicant, prior to issuance of a discharge license, objectively demonstrates to the department's satisfaction that the discharge is necessary, that there are no other reasonable alternatives available and that the discharged effluent is for the purpose of and will assist in the restoration of Atlantic salmon and will return the waters to a state that is closer to historically natural chemical quality.

(a) The department may issue no more than a total of 3 discharge licenses pursuant to this subparagraph and subsection 2, paragraph C, subparagraph (2).

(b) A discharge license issued pursuant to this subparagraph may not be effective for more than 5 years from the date of issuance.

(3) Aquatic pesticide or chemical discharges approved by the department and

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[5] The following standards for classification of fresh surface waters were obtained from: http://janus.state.me.us/legis/statutes/38/title38sec465.html. The State of Maine requires inclusion of the following disclaimer :

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conducted by the department, the Department of Inland Fisheries and Wildlife or an agent of either agency for the purpose of restoring biological communities affected by an invasive species are allowed.

2. Class A waters. Class A shall be the 2nd highest classification.

A. Class A waters shall be of such quality that they are suitable for the designated uses of drinking water after disinfection; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; and navigation; and as habitat for fish and other aquatic life. The habitat shall be characterized as natural.

B. The dissolved oxygen content of Class A waters shall be not less than 7 parts per million or 75% of saturation, whichever is higher. The aquatic life and bacteria content of Class A waters shall be as naturally occurs.

C. Except as provided in this paragraph, direct discharges to these waters licensed after January 1, 1986 are permitted only if, in addition to satisfying all the requirements of this article, the discharged effluent will be equal to or better than the existing water quality of the receiving waters. Prior to issuing a discharge license, the department shall require the applicant to objectively demonstrate to the department's satisfaction that the discharge is necessary and that there are no other reasonable alternatives available. Discharges into waters of this classification licensed prior to January 1, 1986 are allowed to continue only until practical alternatives exist.

(1) This paragraph does not apply to a discharge of storm water that is in compliance with state and local requirements.

(2) This paragraph does not apply to a discharge to Class A waters that are or once were populated by a distinct population segment of Atlantic salmon as determined pursuant to the United States Endangered Species Act of 1973, Public Law 93-205, as amended, if, in addition to satisfying all the requirements of this article, the applicant, prior to issuance of a discharge license, objectively demonstrates to the department's satisfaction that the discharge is necessary, that there are no other reasonable alternatives available and that the discharged effluent is for the purpose of and will assist in the restoration of Atlantic salmon and will return the waters to a state that is closer to historically natural chemical quality.

(a) The department may issue no more than a total of 3 discharge licenses pursuant to this subparagraph and subsection 1, paragraph C, subparagraph (2).

(b) A discharge license issued pursuant to this subparagraph may not be effective for more than 5 years from the date of issuance.

(3) This paragraph does not apply to aquatic pesticide or chemical discharges approved by the department and conducted by the department, the Department of Inland Fisheries and Wildlife or an agent of either agency for the purpose of restoring biological communities affected by an invasive species.

D. Storm water discharges to Class A waters must be in compliance with state and local requirements. [2003, c. 318, §4 (new).]

E. Material may not be deposited on the banks of Class A waters in any manner that makes transfer of pollutants into the waters likely.

3. Class B waters. Class B shall be the 3rd highest classification.

A. Class B waters shall be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; and navigation; and as habitat for fish and other aquatic life. The habitat shall be characterized as unimpaired.

B. The dissolved oxygen content of Class B waters may not be less than 7 parts per million or 75% of saturation, whichever is higher, except that for the period from October 1st to May 14th, in order to ensure spawning and egg incubation of indigenous fish species, the 7-day mean dissolved oxygen concentration may not be less than 9.5 parts per million and the 1-day minimum dissolved oxygen concentration may not be less than 8.0 parts per million in identified fish spawning areas. Between May 15th and September 30th, the number of Escherichia coli bacteria of human and domestic animal origin in these waters may not exceed a geometric mean of 64 per 100 milliliters or an instantaneous level of 236 per 100 milliliters. In determining human and domestic animal origin, the department shall assess licensed and unlicensed sources using available diagnostic procedures.

C. Discharges to Class B waters may not cause adverse impact to aquatic life in that the receiving waters must be of sufficient quality to support all aquatic species indigenous to the receiving water without detrimental changes in the resident biological community. This paragraph does not apply to aquatic pesticide or chemical discharges approved by the department and conducted by the department, the Department of Inland Fisheries and Wildlife or an agent of either agency for the purpose of restoring biological communities affected by an invasive species. [2005, c. 182, §4 (amd).]

4. Class C waters. Class C shall be the 4th highest classification.

A. Class C waters shall be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; and navigation; and as a habitat for fish and other aquatic life.

B. The dissolved oxygen content of Class C water may be not less than 5 parts per million or 60% of saturation, whichever is higher, except that in identified salmonid spawning areas where water quality is sufficient to ensure spawning, egg incubation and survival of early life stages, that water quality sufficient for these purposes must be maintained. In order to provide additional protection for the growth of indigenous fish, the following standards apply.

(1) The 30-day average dissolved oxygen criterion of a Class C water is 6.5

parts per million using a temperature of 22 degrees centigrade or the ambient temperature of the water body, whichever is less, if:

(a) A license or water quality certificate other than a general permit was issued prior to March 16, 2004 for the Class C water and was not based on a 6.5 parts per million 30-day average dissolved oxygen criterion; or

(b) A discharge or a hydropower project was in existence on March 16, 2005 and required but did not have a license or water quality certificate other than a general permit for the Class C water.

This criterion for the water body applies to licenses and water quality certificates issued on or after March 16, 2004.

(2) In Class C waters not governed by subparagraph (1), dissolved oxygen may not be less than 6.5 parts per million as a 30-day average based upon a temperature of 24 degrees centigrade or the ambient temperature of the water body, whichever is less. This criterion for the water body applies to licenses and water quality certificates issued on or after March 16, 2004.

The department may negotiate and enter into agreements with licensees and water quality certificate holders in order to provide further protection for the growth of indigenous fish. Agreements entered into under this paragraph are enforceable as department orders according to the provisions of sections 347-A to 349.

Between May 15th and September 30th, the number of Escherichia coli bacteria of human and domestic animal origin in Class C waters may not exceed a geometric mean of 126 per 100 milliliters or an instantaneous level of 236 per 100 milliliters. In determining human and domestic animal origin, the department shall assess licensed and unlicensed sources using available diagnostic procedures. The board shall adopt rules governing the procedure for designation of spawning areas. Those rules must include provision for periodic review of designated spawning areas and consultation with affected persons prior to designation of a stretch of water as a spawning area.

C. Discharges to Class C waters may cause some changes to aquatic life, except that the receiving waters must be of sufficient quality to support all species of fish indigenous to the receiving waters and maintain the structure and function of the resident biological community. This paragraph does not apply to aquatic pesticide or chemical discharges approved by the department and conducted by the department, the Department of Inland Fisheries and Wildlife or an agent of either agency for the purpose of restoring biological communities affected by an invasive species.

Appendix D. Methodology for total production estimates of American shad and alewife.

In the 1980s, the Maine Department of Marine Resources (MDMR) developed a method of estimating the number of adult American shad and alewife that would be produced by a specific amount of habitat (total production) and the number of adult spawners that would be needed to sustain that total production (spawning escapement). These order-of-magnitude estimates are made primarily for planning purposes, such as sizing upstream passage facilities or determining stocking requirements. Total production is computed by multiplying the total surface area of known or assumed historical spawning habitat by the number of adults produced per unit of spawning habitat (unit production). Spawning escapement is a percentage of total production. Both total production and spawning escapement are computed for specific bodies of water, for example, a river reach or lake. The number of adult fish that need to be passed upstream at each fishway is estimated by dividing spawning escapement needed for all waters above the facility by an assumed passage efficiency (a goal of 90% is typically used). The surface area of spawning habitat for each species was determined from USGS 7.5 minute topographical maps.

American shad
Unit production for American shad is based on information from the Connecticut River, because runs of shad in Maine have not been restored and detailed information on historical abundance is lacking. In the past, MDMR used 111 shad/acre (=2.3 shad/100 yd^2), based on the number of American shad annually passed at the Holyoke Dam during the early 1980s and the amount of habitat between Holyoke Dam and Turners Falls Dam, the next upriver dam. Annual passage numbers for Holyoke from 1980-2004 indicate a slight decline in unit production to 101 shad/acre (2.0 shad/100 yd^2); however, we will use 111shad/acre to maintain consistency with other State fisheries management plans.

Use of 111 shad/acre is further supported by historical information on commercial landings in Maine. A significant fishery for American shad existed in the freshwater tidal section of the Kennebec River and its tributaries after access to inland waters was obstructed by impassable dams at the head-of-tide. From 1896-1906 the average annual landings of American shad in the Kennebec River were 802,514 pounds. This represents 267,500 adult shad, assuming an average weight of three pounds per fish, and a commercial yield of 0.6778 shad/100 $yd^{2.}$ If the exploitation rate ranged from 25-50%, then the total run from Merrymeeting Bay to Augusta (including tributaries) may have ranged from 535,000-1,070,000 shad. This represents a production of to 68-131shad/acre (equivalent to 1.4-2.7 adult shad/100 $yd^{2)}$.

Alewife
Unit production for alewife (235 fish/acre) was developed from the commercial harvest in six coastal Maine watersheds for the years 1971-1983, which was assumed to be 100 pounds/surface acre of ponded habitat. This value was slightly less than the average of the lowest yield/acre for all six rivers, and within the range of yields experienced in other watersheds. Assuming a weight of 0.5 pounds per adult, the commercial yield equals 200 adults/surface acre. The commercial harvest was assumed to represent an exploitation rate of 85%, because most alewife runs were harvested six days per week. Exploitation rates on the Damariscotta River, for example, ranged from 85-97% for the years 1979-1982. When commercial yield is adjusted for the 15% escapement rate, the total production is 235 adult alewives/acre.

The unit production is derived from coastal alewife populations that spawn in lakes and ponds that are relatively rich in nutrients (mesotrophic or eutrophic). Many of the large lakes in the Penobscot basin (e.g. Sebec Lake, Schoodic Lake, and Seboeis Lake) are relatively nutrient poor (oligotrophic) and may not produce 235 alewife/acre. However, MDMR is not aware of any information on alewife production in oligotrophic lakes, and will use 235 fish/acre for planning purposes.

Because Maine's commercially harvested alewife populations began to decline in the mid-1980s under this high exploitation level, MDMR is now recommending that municipalities have a three-day closure for conservation purposes. Therefore, minimum escapement for this plan is assumed to be 45% of total production (equivalent to a three-day closure).

Appendix E: Conceptual Restoration Monitoring Plan for Fisheries Resources Affected by the Penobscot River Restoration Project

September 20, 2006

Prepared for the Penobscot River Science Steering Committee
by
The Fisheries Subcommittee
Joan G. Trial - Chair

I. INTRODUCTION

In June 2004, a final agreement was signed by PPL Maine, LLC (PPL), federal, state, tribal and conservation interests effectively resolving outstanding fish passage, tribal, and other issues associated with the Federal Energy Regulatory Commission (FERC) relicensing of PPL's hydroelectric projects located in the lower reaches of the Penobscot River. Among the various components contained in the June 2004 settlement agreement, PPL agreed to sell three hydroelectric projects (Veazie, Great Works, and Howland Dams) to the Penobscot River Restoration Trust for eventual removal[6]. The Penobscot River Restoration Trust is a non-profit conservation coalition comprised of representatives from the Penobscot Indian Nation, American Rivers, Atlantic Salmon Federation, Maine Audubon, Natural Resources Council of Maine, and Trout Unlimited established for the purpose of implementing the purchase and removal of the lower Penobscot River dams. The settlement agreement also provides for improved fish passage at four other PPL dams on the Penobscot River (Orono, Stillwater, Milford, and West Enfield). It is anticipated that successful implementation of the settlement agreement (referred to as Penobscot River Restoration Project, "PRRP") will result in the restoration of various ecosystem functions in the Penobscot River including restoration of diadromous fish resources. Figure 1 below depicts existing hydroelectric dams in the lower Penobscot River including those identified for eventual removal.

Monitoring the ecosystem response to implementing the PRRP is critical to adaptively managing and conserving diadromous fish resources in the Penobscot River. Because restoration projects can involve a combination of active and passive restoration techniques, each with some level of uncertainty, it is critical to implement a well-designed monitoring plan (USGS 2005). Additionally, because of the spatial and temporal scale of restoration projects, it may be necessary to re-evaluate the restoration effort at various intervals to make necessary adjustments if monitoring indicates that one or more assumptions of the project were incorrect (USGS 2005). Only through a monitoring process closely linked to an adaptive management protocol can the success of ecosystem restoration be adequately evaluated (USGS 2005).

[6] The Howland Project may be decommissioned and have a nature-like fishway installed if found feasible.
September 20, 2006

This conceptual plan presents an approach for monitoring restoration of fisheries resources in the Penobscot River. According to the Federal Interagency Stream Restoration Working Group (1998), a conceptual model can be a useful tool throughout the planning process. This monitoring plan has been reviewed and endorsed by the fisheries subcommittee of the Penobscot River Science Steering Committee. The Penobscot River Science Steering Committee was organized by the University of Maine's Mitchell Center and Penobscot River Restoration Trust to organize and oversee scientific research and monitoring related to the restoration project. Members of the fisheries subcommittee include representatives from the Maine Atlantic Salmon Commission, Maine Department of Marine Resources, Maine Department of Environmental Protection, Maine Department of Inland Fisheries and Wildlife, University of Maine, U.S. Fish and Wildlife Service, and NOAA's National Marine Fisheries Service. Comments on a draft plan from fisheries biologist from the Connecticut Department of Environmental Protection, University of New Brunswick, and Michigan State University were incorporated into this conceptual plan.

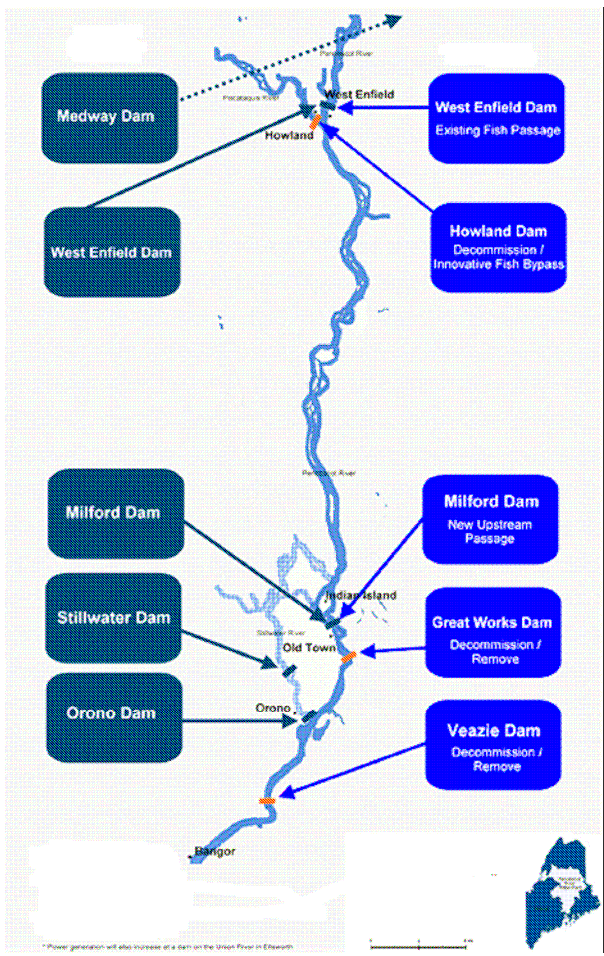

Figure 1. Relative location of hydroelectric dams in the lower Penobscot River. (From Penobscot River Restoration Trust website with permission).

II. GOALS AND OBJECTIVES

Restoration monitoring has been classified into at least three overlapping categories including: implementation, effectiveness, and validation (Block et al., 2001; USFWS 2000; Federal Interagency Stream Restoration Working Group 1998). Implementation monitoring is used to assess whether or not a directed management action was carried out as designed. Effectiveness monitoring is used to determine whether the restoration action was effective in attaining the desired goals of the project. Validation monitoring is used to verify basic assumptions and scientific understanding concerning the restoration techniques and principals. The types of monitoring particularly relevant to fisheries resources affected by the PRRP are validation and effectiveness monitoring. Thus, this plan focuses on both validation and effectiveness monitoring (hereafter referred to collectively as “restoration monitoring”) of diadromous fish resources in the Penobscot River watershed.

According to Roni et al. (2005), the overall goals of a restoration project and the objectives of the monitoring program must be clearly laid out prior to initiating a study to evaluate restoration actions. Goals are typically broad and strategic while objectives should be more specific and quantifiable (Roni et al. 2005). An overall goal of the PRRP is to “restore self sustaining populations of native sea-run fish”. To achieve this goal, the PRRP will implement the following specific actions intended to recover diadromous fish populations in the Penobscot River:

- Veazie and Great Works Dams - Decommission and removal;
- Howland Dam - Decommission and install a nature-like fishway;
- Orono Dam - Install new upstream fish trapping facility. Install upstream American eel fishway(s). Continue operation of existing downstream passage facilities.
- Stillwater Dam – Install upstream fishway(s) for American eels. Install new downstream passage facilities.
- Milford Dam - Install new state-of-the-art upstream fishlift and discontinue use of existing Denil fishway. Install upstream fishway(s) for American eels. Install new downstream passage facilities.

Habitat alterations such as those proposed in the PRRP can be expected to result in changes to: 1) total fish biomass and production, 2) temporal and spatial fish community structure (i.e., species richness, distribution of biomass, and production), 3) biomass, production, and community structure of other biotic elements (e.g., mussels, macroinvertebrates, nutrients), and 4) abiotic elements of the ecosystem (Minns et al. 1996). To assess the goal of restoring self-sustaining populations of diadromous fish, monitoring must not only encompass fish populations, but the entire web of aquatic relationships on which diadromous fish depend (USGS 2005). In managing fish assemblages, it is important to determine if other biotic components have increased, decreased, or changed in species composition following habitat restoration activities (Minns et al. 1996). It seems from past diadromous fish recovery efforts that recovery cannot succeed if all efforts are single-species focused. Successful recovery of diadromous fish requires restoring entire ecosystems.

Studies of fishes can occur at the individual, population, and community levels (Minns et al. 1996). Restoration monitoring in the Penobscot River will be based on indices at each of these levels of organization to understand the range of ecosystem functions potentially affected by the PRRP. Therefore, this plan proposes the following objectives to determine aquatic resource responses to the PRRP:

Objective 1: Monitor abundance, biomass, and production of diadromous (e.g., Atlantic salmon, shortnose sturgeon, Atlantic sturgeon, American shad, river herring[7], rainbow smelt, sea lamprey, and American eel) and resident fish populations.
Objective 2: Monitor diadromous and resident fish assemblages (e.g., species richness, distribution).
Objective 3: Monitor other aquatic resources including nutrients, macroinvertebrates, and mussels .
Objective 4: Monitor abiotic aquatic habitat.

To accomplish these objectives, the following key monitoring questions will need to be assessed as part of this restoration monitoring plan. These will form the basis for judging the success of the PRRP in restoration of diadromous fish species to the Penobscot River.

Objective 1: Monitor Fish Abundance, Biomass and Production

- Has diadromous or resident fish abundance, biomass, and production changed in the river?
- Have the number of returning adult diadromous fish in the river changed specifically in response to the PRRP?
- Has juvenile diadromous fish escapement changed in the river?
- Have predator-prey population dynamics changed in the river?

Objective 2: Monitor Fish Assemblages

- Has species richness changed in the river?
- Have spatial fish distributions changed in the river?
- Has the rate of diadromous fish recolonization of historic habitat changed in the river?
- Have upstream and downstream migration and survival rates for diadromous fish changed in the river?
- Has freshwater residency time of diadromous fish changed in the river?
- Has the reproductive fitness of fish in the river been altered?
- Have growth rates changed in the river?

Objective 3: Other Biotic Responses

- Has non-finfish species (e.g., mussels, macroinvertebrates) richness, abundance, or distributions changed in the river?
- Have trophic level interactions changed in the river?
- Has production of marine-derived nutrients for various trophic levels changed in the river?

Objective 4: Monitor Abiotic Responses

- Has water quality (temperature, dissolved oxygen, etc.) changed in the river.
- Has the amount of impounded, riffle, or run habitat changed in the river?

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[7] Alewife and blueback herring

- Has habitat for macroinvertebrates and other forage species changed in the river?

III. MONITORING STUDY DESIGN

A. General Approach

There are many potential study designs for monitoring single or multiple restoration actions (Roni et al. 2005). According to Minns et al. (1996), the specification of statistical designs for assessing environmental responses to habitat restoration has been advancing rapidly. Numerous texts and published papers have described alternative approaches for evaluating the effects of habitat restoration projects on ecosystems. Most study designs, however, are generally based on whether data are collected before and after treatment and whether they are spatially replicated or involved in single or multiple sites (Roni et al. 2005; Gerstein 2005).

Four widely used study designs for conducting restoration monitoring include: 1) post-treatment, 2) reference, 3) before-and-after (BA), and 4) BA with a control site. The application of each of these study designs for the PRRP has various strengths and weaknesses. Post-treatment designs are retrospective studies conducted without the benefit of pre-treatment (baseline) data (Roni et al. 2005; Gerstein 2005; Minns et al. 1996). While many studies have conducted post-treatment restoration monitoring studies, there are difficulties with these studies (Harris et al. 2005). The main drawback is that pre-treatment conditions and history are unknown so that considerable variability cannot be taken into account (Harris et al. 2005). Smith (1998) suggests that the results of post-treatment studies are often just preliminary. Because there are pre-treatment data pertaining to diadromous fish resources, aquatic habitat, and water quality for the Penobscot River watershed and opportunities to gather more extensive data, a post-treatment study design is not recommended for restoration monitoring of the PRRP.

The “reference” study design has also been used to monitor habitat restoration activities (Harris et al. 2005; Gerstein 2005). The reference study design compares restored sites to reference sites assumed to be comparable. A reference study of the PRRP is not possible because no other large river system exists in Maine that could be used as a reference site. Habitat throughout much of the large river systems in Maine has already been previously altered through dam construction. Thus, a reference study design is also not recommended.

The BA study design is the recommended approach for many applications involving stream restoration (Kocher and Harris 2005). The BA study design is recommended for studies in which several to many projects are to be sampled (Gerstein 2005). The BA study design allows for knowledge of pre-treatment conditions and natural variability (Gerstein 2005; Minns et al. 1996). For valid BA studies, good baseline data are required (Koldolf 1995; Minns et al. 1996). The main drawback of the BA design is that results can take years to manifest since it relies on the performance of the habitat restoration. BA study designs have been classified into several different types depending upon observation intensity (number of study sites, reaches, watersheds) and existence of controls (Roni et al. 2005). A common approach is the before-and-after control impact design (BACI) where a control site is evaluated over the same time period as the treatment site. The addition of a control site to a BA study design is meant to account for environmental (natural or otherwise) and temporal trends found in both the control and treatment sites (Roni et al. 2005). A BACI design with a poorly chosen control site can be less powerful than an uncontrolled before-and-after study design (Roni et al. 2005). Because the PRRP involves the lowermost reaches of the Penobscot River, it is expected that the results of the project will affect diadromous fish resources throughout much of the Penobscot River watershed. As a result, suitable control sites are not likely to be available in the watershed. For these reasons, a straightforward BA study design is most appropriate for evaluating the PRRP. To determine whether the project has achieved it objectives, restored conditions should be compared to pre-treatment conditions.

B. Monitoring Parameters

The effects of dam removal activities on biotic and abiotic resources in the Penobscot River could take from several years to decades to be fully manifested in the ecosystem. The transition period following dam removal, natural variations in fish and non-finfish populations, life cycle periods, riparian recolonization, and many other factors will affect the ecosystem response to dam removal in the Penobscot River. Recognizing the levels of funding and staffing needed to perform habitat restoration monitoring studies at a watershed scale, this plan attempts to present an attainable timetable and scale for pre- and post-treatment monitoring.

To monitor the effects of the PRRP, this plan identifies five (5) discrete before-and-after monitoring studies for the Penobscot River: 1) fish population studies; 2) fish movement studies; 3) juvenile migrant sampling, 4) estuarine hydroacoustics study, 5) marine derived nutrient studies, and 6) non-biotic monitoring program. The successful completion of these studies will adequately address the four stated objectives of this monitoring plan. To perform BA studies, pre-treatment data are essential. Fortunately for this study, baseline data pertaining to fisheries, habitat, and water quality is generally available for the Penobscot River watershed. Researchers from the Maine Atlantic Salmon Commission, Maine Department of Fish and Wildlife, University of Maine, Maine Department of Environmental Protection, NOAA Fisheries, Midwest Biodiversity Institute, hydroelectric owners, and others have been collecting biological and environmental data throughout the Penobscot River for many years. Much of these data could be used to portray baseline biological and environmental data for the watershed. The University of Maine's Mitchell Center is currently compiling a literature review and data inventory of past and current research in the Penobscot River and its watershed. The information should be available in 2006 and will be used to further refine monitoring activities identified in this plan.

The sequence and timing of dam removal activities in the Penobscot River may affect the collection of pre- and post-treatment data. At this time, it is not known whether dam removal at Veazie and Great Works and/or installation of the Howland nature-like bypass will occur simultaneously in a single construction season or individually over several years. To the extent practical, it is recommended that all pre-treatment data be collected concurrently prior to any dam modifications in the river.

<u>Fish Population Studies</u>

Fish population studies will need to be conducted in the Penobscot River before and after dam removal to monitor multiple metrics for fish at the individual, population, and assemblage levels. There are many potential study designs that could be used to monitor the response of fish to restoration actions in the Penobscot River ranging from simple relative abundance studies to complex stock assessments. This plan proposes to continue the use of the Index of Biotic Integrity (IBI) data collection protocols in the Penobscot River to assess the effects of the PRRP. Catch per unit effort data based on standard IBI protocols have been collected in the Penobscot River periodically since 2004 and provide important pre-treatment (baseline) data of fish populations. The continuation of these protocols will ensure continuity of data and facilitate before and after comparisons of restoration effects on fish populations.

Karr (1981) introduced the IBI concept of multimetric indices to assess aquatic assemblages. The IBI method integrates biotic responses by examining population and community patterns and processes (Karr 1981; Karr et al. 1986; NRCS 2003). The IBI uses fish sampling data to indicate the overall health and integrity of a stream.

Currently, sampling protocols are being developed for large Maine rivers (Yoder and Kulik 2003; Yoder 2005). Sample sites have been established in several Maine rivers including the Penobscot River. In 2004, 46 sites were sampled using the protocols throughout the lower, middle, and upper reaches of the Penobscot River and the following tributaries: Mattaawamkeag River, Piscataquis River, and Passadumkeag Stream (Yoder 2005). The Stillwater Branch of the Penobscot River was also sampled. Several sites were re-sampled in 2005 near Old Town and Lincoln, Maine. These studies provide baseline data on diadromous and resident fish resources in the Penobscot River for this restoration monitoring study. To supplement existing baseline data, additional fish community assessment using the developed protocol should occur for two years prior to dam removal and fishway installation activities in the river. Tentatively, sampling should also be repeated during 1, 3, and 5 years following the completion of restoration activities to provide post-treatment monitoring information. This would provide essential data concerning fish abundance, biomass, and fish assemblages (species richness, recolonization, etc.) related to river restoration goals and objectives (see Objectives 1 and 2). For purposes of this conceptual plan, specific sample sites, metrics, and statistical analyses will need to be determined by researchers involved in the PRRP. Its quite possible that additional post-treatment data will be needed beyond the 5th year to adequately assess both small and large-scale changes to fish assemblages in the Penobscot River. Researchers involved in the PRRP will determine the need for additional post-treatment fish community data.

Fish Movement Studies

As part of the PRRP, the Veazie and Great Works Dams will be removed. The Howland Dam may be partially removed and a new, nature-like fishway will be installed.

Implementation of the PRRP will also result in the installation of several new upstream and downstream fish passage facilities at PPL Maine's dams in the lower Penobscot River (see Section II and Figure 1). Dam removals and installation of these new fishways could have a number of effects on diadromous fish assemblages in the river including upstream and downstream migration and survival rates, adult returns, juvenile escapement, colonization, and distribution. To assess the effects of these actions in restoring diadromous fish, pre- and post-treatment fish movement studies will need to be conducted in the Penobscot River. However, because Atlantic salmon are the only anadromous fish species that presently occur in the Penobscot River above the Veazie Dam in any significant numbers, it will not be possible to conduct pre-treatment BA movement studies for other anadromous fish species that may be restored to the river as a result of the PRRP.

Fishway records in the Penobscot River provide useful pre-treatment fish movement information for Atlantic salmon. At present, fishways are monitored at the Veazie and Weldon Dams. The Veazie Dam is the first dam on the Penobscot River while the Weldon Dam is the fifth and final mainstem dam on the Penobscot River. The Veazie Dam fishway has been monitored since 1978 (Baum 1997). At the Weldon Dam, the fishway has been monitored since 1983 (personnel communication, Kevin Bernier, Fisheries Biologist, Brascan Power New England, October 21, 2005). Following implementation of the PRRP, fish passage monitoring data collected at the Milford, Orono, and Weldon Dams can be used to assess post-treatment movements of Atlantic salmon and other diadromous fish species. It is expected that fishway monitoring at the facilities will continue for a number of years following implementation of the PRRP.

A number of upstream and downstream pre-treatment fish passage restoration monitoring studies for Atlantic salmon have been conducted in the lower Penobscot River. During the late 1980s and early 1990s, fish passage effectiveness studies for Atlantic salmon were conducted at PPL Maine hydroelectric dams using radio telemetry (Hall and Shepard 1990a; Hall and Shepard 1990b; Shepard 1989a; Shepard 1989b; Shepard 1991a; Shepard 1991b; Shepard 1991c; Shepard 1993; Shepard 1995; Shepard and Hall 1991). In 2002-2005, upstream Atlantic salmon movement studies were performed in the lower Penobscot River using Passive Integrated Transponder (PIT) tag detection arrays at multiple fishways in the river (Beland and Korsky 2003). The University of Maine is currently conducting a downstream smolt movement study using ultrasonic telemetry techniques in the Penobscot River. These data, along with post-treatment effectiveness testing that will be collected by PPL Maine at the Milford, Orono, and Stillwater[8], may be used to describe the effects of the new fishways on Atlantic salmon movements in the lower Penobscot River. To understand the combined effects of new fishways and the removal of the Great Works and Veazie Dams on anadromous species, movement studies using PIT tags and ultrasonic telemetry should be performed following implementation of the PRRP. These studies will provide essential information concerning migration and survival rates for anadromous fish species and should be conducted under a variety of river conditions including low, median, and high river flows and at dams not affected by the PRRP (Orono, Stillwater, Milford, West Enfield).

Additional studies concerning Atlantic salmon movements will be needed at the nature-like fishway at the Howland Dam. For purposes of this conceptual plan, at least two (2) years of post-treatment effectiveness and validation studies using radio telemetry techniques, PIT tags, or some other method should be conducted with Atlantic salmon at the nature-like fishway at Howland. Data collected at the nature-like fishway can be contrasted to historical fishway effectiveness data at the Howland Dam to document the effects of the PRRP.

Following implementation of the PRRP, PLL Maine must conduct fishway effectiveness studies at the Milford, Stillwater, and Orono Dams for a variety of anadromous fish species and American eel. With the exception of Atlantic salmon, these data cannot be used for BA study protocols. However, it will provide useful post-treatment information for the river.

Juvenile Migrant Sampling

NOAA Fisheries' Maine Field Station has assessed Atlantic salmon smolt populations in the lower Penobscot River since 2000. The Maine Field Station annually deploys three rotary screw traps to capture migrating smolts downstream of the Veazie Dam. The Maine Field

[8] The FERC licenses for the Milford, Stillwater, and Orono Dams requires fishway effectiveness studies.

Station has also performed similar assessment work on the Narraguagus, Sheepscot, and Pleasant Rivers. The primary purpose of rotary smolt trapping operations is to sample Atlantic salmon smolts to estimate the number of smolts emigrating, and to gain a better understanding of their ecology. Other species of resident and diadromous fish are routinely collected during trapping operations (Table 1) and rotary screw traps can be effective for collecting American eel, alewives, rainbow smelt, and American shad.

Table 1. Summary of diadromous fish caught per river by rotary screw traps. Penobscot River and Narraguagus Rivers sampled annually since 2000. Sheepscot River sampled in 2002, 2004 and 2005; Dennys River sampled in 2005.

River	Salmon Smolt	Rainbow Smelt	American Eel	Alewife	American shad
Penobscot	5,781	~9,423	1,626	179	0
Sheepscot	409	218	847	8,830	36
Narraguagus	2,312	196	1665	9,861	5
Pleasant	1,280	9	132	1,986	3
Dennys	549	5	25	0	0
Total	10,331	~9,851	4,295	20,856	44

Rotary screw trap data collected in the lower Penobscot River provides useful baseline restoration monitoring data. As part of the BA study design for this restoration monitoring plan, NOAA Fisheries Maine Field Station should deploy and monitor two (2) rotary screw traps in the lower Penobscot River from April through November at least two years prior to dam removal actions. An April – November sampling effort is designed to coincide with the outmigration seasons for smolts, alewives, shad, and American eel. Rotary screw trap should be sampled at least every 24-48 hrs weekly throughout this period depending upon flow and river conditions[9]. To provide post-treatment monitoring data, this effort should be continued during the 1st, 3rd, and 5th years following implementation of the PRRP or more frequently if feasible. Additional post-treatment data may be needed beyond the 5th year interval to adequately characterize both small and large-scale changes to smolt populations in the Penobscot River. The need for additional post-treatment smolt data will be made by researchers involved in the PRRP following statistical analysis of all data collected following the fifth year of dam removal. Data collected during rotary screw trap sampling may also be used to calibrate proposed estuarine hydroacoustics sampling in the Penobscot River (see below).

Estuarine Hydroacoustics Sampling

Hydroacoustic assessment is an accepted methodology for presence, distribution, biomass, and behavior of fish and other aquatic fauna. Fisheries hydroacoustics are used to detect fish, and other aquatic organisms, by the use of sound transmitted in water. Either fixed or mobile hydroacoustics could be used to assess estuarine fish populations. Any estuarine study will likely also monitor environmental factors including salinity, temperature, and particle transport - all factors influencing fish and prey presence in the estuary. Specific objectives of a hydroacoustic monitoring program are:

[9] RSTs require at least 6 feet of water depth to work properly. Low and high river flows may limit RST sampling in the river during the proposed sampling period.

- Deploy fixed or operate mobile, commercially available hydroacoustic and environmental monitoring gear to collect data on fish presence, zooplankton presence, and environmental conditions in the Penobscot River estuary.
- Optimize deployments to monitor the entire river width using hydroacoustics.
- Verify targets (fish and other) to lowest group possible using hydroacoustics.
- Optimize and calibrate hydroacoustic gear for monitoring individual fish species and prey abundance.
- Initiate monitoring of phytoplankton abundance.
- Establish indices for determining fish abundance.
- Characterize seasonal fish presence/absence data.
- Characterize the impacts of environmental conditions (primary productivity, temperature, salinity, flow, particle dynamics, prey abundance) on fish presence and movement patterns.

A hydroacoustics study of the Penobscot River estuary will provide important data pertaining to pre-treatment conditions of fish assemblages, ecology, and environmental conditions. In order to provide post-treatment monitoring data, the hydroacoustic study should continue for at least 2-5 years after implementation of the PRRP. Researchers involved in the PRRP will determine the need for additional post-treatment data. In addition to fixed surveys, mobile hydroacoustic surveys of the estuary would also provide important data concerning fish populations.

Marine-Derived Nutrient Studies

Upon their return from the sea, anadromous salmonids provide marine-derived nutrients to freshwater ecosystems through excretion, gametes, and carcasses (Winter et al. 2000). These nutrients can be important to the productivity of the lakes and streams in which they spawn and to their progeny (Winter et al. 2000). These nutrients can be directly consumed by fishes or are reduced by bacteria, invertebrates, and fungi. Increased nutrient production can increase invertebrate, bacteria, and fungi diversity, numbers, and growth rates and then lead to increased fish growth rates (Winter et al. 2000). While the dynamics and ecological significance of nutrient cycling by anadromous fish species assemblages in west coast ecosystems has been well established, the scientific basis and biological significance to Atlantic salmon and other co-evolved east coast anadromous fishes (clupeids, sea lamprey, or Atlantic salmon themselves) is less well studied or understood at this time (Garman and Macko 1998; MacAvoy et al. 2000, Nislow et al. 2004).

To understand the influence of organic materials and nutrients from anadromous fish affected by the PRRP, nutrient concentrations, biomass, isotopic signatures and production of algae, macroinvertebrates, and finfish could be monitored before and after removal of the Penobscot River dams. A detailed description of appropriate methods and statistical analyses of such studies is beyond the scope of this conceptual plan.

Non-Finfish and Abiotic Monitoring Program

Implementing the PRRP will significantly alter aquatic habitat in the lower Penobscot River through removal of the Veazie and Great Works Dams and installation of a nature-like fishway at the Howland Dam. Objectives 3 and 4 of this monitoring plan calls for a BA assessment of non-finfish and abiotic responses important to diadromous fish species in the Penobscot River.

Pre-treatment water quality data (temperature and dissolved oxygen) for the lower Penobscot River has been collected by the Maine Department of Environmental Protection (MDEP), Penobscot Indian Nation, PPL Maine, and others for many years. In 2003, the MDEP published the results of water quality modeling using QUAL2EU for the Penobscot River (MDEP 2003). Using water quality data collected in the river during 1997 and 2001, the MDEP model predicts water quality including temperature and dissolved oxygen throughout the Penobscot River from Millinocket to Bucksport. It is expected that these data along with other data collected by PIN and PPL Maine is adequate to describe pre-treatment water quality conditions in the lower Penobscot River. To assess post-treatment water quality conditions, water quality sampling should occur in the Penobscot River following implementation of the PRRP. Water quality sampling should occur from the Howland Project downstream to Bangor under a variety of river flows including low, median, and high river flows. Specific protocols for water quality monitoring will need to be established by researchers involved in the PRRP.

Aquatic habitat in the vicinity of the Veazie, Great Works, and Howland Dams should also be mapped before and after implementation of the PRRP (including the proposed nature-like fishway at Howland). This information will be essential to describe the effects of the PRRP in restoration aquatic habitat for fish, prey, and macroinvertebrate species in the river. Habitat should be mapped to scale as run, riffle, and pool (at an appropriate scale) and geo-referenced using a Global Positioning System.

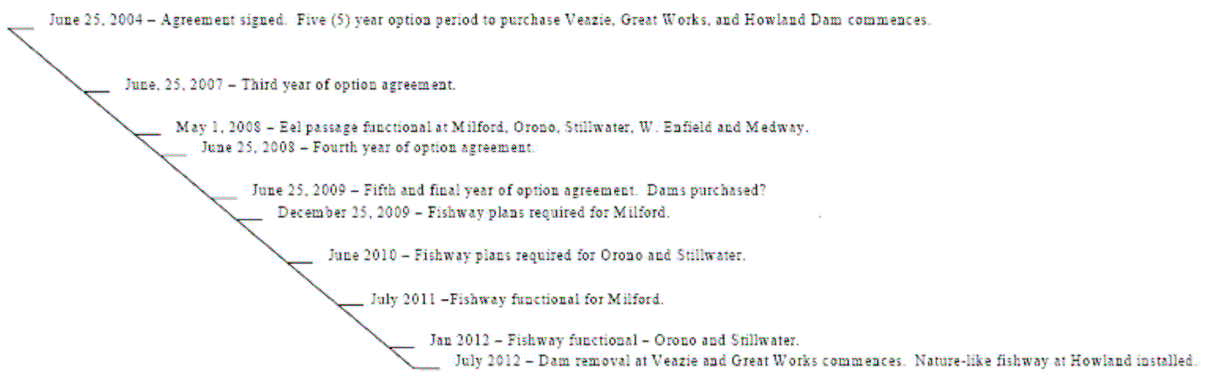
C. Data Analysis

The statistical methods used to analyze data collected during restoration monitoring should be based on the monitoring design, the parameters selected, and the data collected (Roni et al. 2005). There are a number of common multivariate statistical approaches that have been used to test hypotheses regarding restoration activities including parametric tests (e.g., t-tests, analysis of variance), regression and correlation, non-parametric tests (e.g., Mann-Whitney tests, Wilcoxon paired rank test, Kruskal-Wallis analysis of variance), multivariate techniques (e.g., cluster analysis, discriminant analysis), and others. However, a detailed description of appropriate statistical analyses or models is beyond the scope of this conceptual plan. Rather, researchers involved in the PRRP should determine the appropriate statistical analyses.

Ultimately, data collected during monitoring studies should be analyzed to assess the progress of achieving restoration goals for the Penobscot River. The Maine Atlantic Salmon Commission along with other state and federal resource agencies are presently preparing a multi-species fisheries management plan for the Penobscot River. The multi-species management plan will develop species-specific restoration goals for the Penobscot River based upon habitat, water quality, species life history, etc. To assess the success of the PRRP, a whole-life history model could be developed using data collected during monitoring studies. Estimates of age/size specific survival, growth, fecundity, etc. could be weighted by production goals to identify where restoration bottlenecks exist in meeting restoration goals. Also, data collected during restoration monitoring studies could be used to periodically calibrate species-specific restoration goals of the management plan within a whole-life history model.

IV. TIMELINE

The timeline for implementing the PRRP was established by the Penobscot River Comprehensive Settlement Accord filed with the FERC in June, 2004. In accordance with the Settlement Accord, the five-year option period to purchase the Veazie, Great Falls, and Howland Dams expires in June, 2009 (see below). Assuming the dams are purchased on the fifth and final year of the option period and two to three years will be needed to permit dam removal activities, it is anticipated that the Veazie and Great Works Dams could be removed in 2012. The Howland Dam nature-like fishway could also be installed in 2012.



V. FUNDING

The following table provides preliminary cost estimates for conducting BA restoration monitoring studies in the Penobscot River. Cost estimates include sampling, data analysis, and reporting. Potential funding sources for studies have also been identified.

Study	Estimated Number of Years	Annual Cost Estimate ($1,000)	Funding Source
Fish Population Studies	5	50-90	Grants
Smolt Movement (ultrasonic telemetry)	4	125-150	Grants
Adult Salmon Movement (PIT tagging)	4	25--50	Grants
Howland Nature-Like Fishway Effectiveness	2	50-75	Penobscot Partners
Fishway Monitoring	5	75-100	PPL Maine
Milford, Orono, and Stillwater Fishway Effectiveness	2-3	150-200	PPL Maine
Juvenile Migrant Sampling (rotary screw traps)	5	50-75	NOAA PRD/NEFSC
Estuarine Hydroacoustics Sampling	5	150	Grants
Water Quality	3	50	Grants
Habitat Mapping	2	50-75	NOAA Restoration Center
Marine Derived Nutrients	2-3	50-75	Grants

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